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Original Article

Spirometry Prediction Equations for North-eastern Indian Population

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Abstract

The spirometry prediction equations of healthy adults of northeastern region of India was intended in which 711 (544 male and 167 female) volunteers in the age range 18-60 years were participated. The PTF parameters include forced vital capacity (FVC), forced expiratory volume in first one second (FEV_1), FEV_1/FVC%, peak expiratory flow (PEF) and forced expiratory flow during the middle half of forced vital capacity ($FEF_{25-75\%}$). Linear regression models were developed for FVC, FEV_1, and PEF for male and female in which age and body height was taken as independent variable. The mean value of FVC, FEV_1, FEV_1/FVC%, PEF and $FEF_{25-75\%}$ was observed 3.28 L, 2.87 L, 87.3%, 7.2 L/s and 3.29 L/s, respectively, for male which is significantly higher ($p<0.001$) than female. The coefficient of determination of the developed regression models of FVC and FEV_1 were observed in the range of 0.315-0.367. The developed prediction equations can be used for evaluating the reference value of spirometry parameters of healthy adult of northeastern part of India in both epidemiology studies and clinical use.

Introduction

Spirometry prediction equation is a reference value of pulmonary function parameters for non-smoking healthy adults. The *spirometry* prediction equations depends on age, gender, body stature, habituation to physical activity, smoking habits, besides social-economic status, environmental condition, altitude and ethnicity (1, 2). The pulmonary function parameters mainly includes the forced vital capacity (FVC), forced expiratory volume in first one second (FEV_1), FEV_1/FVC %, peak expiratory flow (PEF) and forced expiratory flow during the middle half of forced vital capacity ($FEF_{25-75\%}$).

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The *spirometry* prediction equation is very essential tool to interpret the functioning of individual's pulmonary function which can be measured from spirometer. Some studies have been reported (3, 4, 5 and 6) on pulmonary functions prediction equations of healthy adults for Eastern, Western, Northern and Southern populations of India. The maximum FVC and FEV_1 for male was reported for Western (4.11 L, 3.65 L) (4) followed by Northern (4.07 L, 3.29 L) (5) Eastern (3.71 L, 3.09 L) (3) and Southern (3.53 L, 3.02 L) (6) part of India. However, for female maximum

FVC and FEV_1 was reported for Western and minimum for Southern part of India. Chhabra (7) reported that, the maximum FVC was found in northern India followed by Eastern, Western and Southern India up to the age of 15-40 years. However, above 40 years age group maximum FVC was observed in northern India followed by Eastern and Western India. Also it was reported that the spirometry parameters differences with other region of India were not found uniformly. FVC of Northern volunteers was always greater than FVCs predicted from other regional equations except Eastern FVC up to the age 40 years. The greater FVC of northern equation was observed mainly in lower ranges and in volunteers with larger FVC. The average PEF for western (4) and northern (5) regions were reported as 8.45 and 8.01 L/s. This clearly indicates the effect of geographical difference on FVC and FEV_1. The northeastern region comprises a 2.6×10^5 square kilometers geographical area (8% of total India) which has unique socio-demographic pattern but grossly lacking the prediction equations of pulmonary functions of these populations. The people of this region are also accustomed to vastly different local dialects and languages. Therefore, this study was undertaken to find out the spirometry prediction equations of non-smoking healthy adults of the inhabitants of northeastern part of India and compared the developed prediction equations with the prediction equations of other part of the country.

Materials and Methods

Study population

The present study was carried out during the 2015-16 at North Eastern Regional Institute of Science and Technology, Arunachal Pradesh where all the eight northeastern states students study. The students, staffs and faculty members of the Institute were volunteered for the study. The study was approved by the Institutional Ethics Committee. Total 920 volunteers, in the age range of 18-60 years, were called for the study and after initial selection process total 711 healthy non-smoking volunteers (544 males and 167 females) was included in the study. About 50 per cent of the selected volunteers were in the age range of 21-30 years. The essential criteria to include the volunteers in this study who (a) correct posture with head slightly elevated (b) inhale rapidly and completely (c) position of the mouthpiece (d) exhale with maximal force were followed as per the ATS guidelines and ERS recommendations (8) Those volunteers were excluded from the study who (a) could not perform spirometry test as per ATS guidelines (9, 8), (b) had a history of asthma, chronic bronchitis, chronic cough, exposure to any toxic chemicals, or surgery involving the chest wall or spine, and had ongoing respiratory symptoms (10), (c) had smoking habit of at least 1 cigarette/day for than a year. Personal demographic data such as body height (cm), body weight (kg), age (yrs) and health information of the volunteers were also taken before the spirometry test.

Pulmonary function test

The volunteers were instructed (a) not to take heavy meal at least two hours, (b) not to take drugs/drinks containing caffeine, (c) not to smoke and (d) not to undertake heavy physical activity before performing spirometry.

The spirometry was conducted using portable micro-quark spirometer, with Omnia 1.2 software (COSMED the metabolic company, Via dei Piani di Monte Savello, Albano Laziale – Italy). The apparatus was calibrated daily before the test and operated within the ambient temperature range of 18–27°C. The spirometry parameters included five parameters namely (i) forced vital capacity (FVC), (ii) forced expiratory volume in one second (FEV_1), (iii) forced expiratory ratio (FEV_1/FVC, %), (iv) peak expiratory flow (PEF) and (v) force expiratory flow fraction between 25 to 75% ($FEF_{25-75\%}$). The spirometry test of volunteers was performed in sitting position using a nose clip. The tests were repeated minimum three times after adequate rest and no more than eight as per the ATS guidelines (8) and the best results were taken for subsequent analysis. The observed spirometry parameters were compared with the other peer publications for Indian population (3, 4, 5 and 6).

Data Analysis

The collected spirometry data were divided into two groups male and female because of the significant difference ($p<0.01$) between the genders. The data were presented in terms of mean and standard deviation. The collected data were tested for normality of distribution by z-values of Skewness and Kurtosis. If z-value lied between -1.96 to +1.96 was considered normal distribution and it was found FVC, FEV_1 and PEF were normally distributed for both genders whereas, among the anthropometric parameters only body height was normally distributed for male volunteers.

The variable importance in the projection (VIP) was also carried out using XLSTAT to know the influence of body height, body weight and age on the measured spirometry parameters. The VIP value indicates no, moderate and high influence of the independent parameter if it is less than 0.8, within 0.8 to 1 and greater than 1, respectively (11, 12). It was observed that the spirometry parameters were not influenced by body weight (VIP<0.8) whereas body height (VIP>0.8) and age (VIP>1) were highly influenced for male and female both. Hence, the body weight was excluded from the study.

The linear regression analysis was performed for FVC, FEV_1 and PEF for male and female separately with body height and age as the independent variables. The fitness of regression was interpreted based on standard error estimation, coefficient of determination and p-value. These predicted values from the developed model were compared with the corresponding observed parameters by independent-sample t-test for both male and female volunteers. Further, the developed regression models for spirometry parameters were compared with the similar existing models for different regions of India (3, 4, 5 and 6). Also, bias percentage and RMSE were calculated to find out the accuracy of the developed models and differences with other models.

Results

The mean and standard deviation of the demographic parameters of the selected volunteers such as age, body height, body weight and BMI are shown in Table I. It was observed that all demographic factors are significant between male and female ($p<0.001$) except age ($p>0.05$). The table also presents the mean value of measured spirometry parameters namely FVC, FEV_1, FEV_1/FVC, PEF and $FEF_{25-75\%}$ for male and female. The spirometry parameters were also found significant between genders. The average spirometry parameters of female volunteers observed 33 to 38% less compared to male volunteers.

TABLE I: Anthropometric and spirometry parameters of healthy non-smoking volunteers.

Parameter	Males (N=544)		Females (N=167)	
	Mean	*SD*	*Mean*	*SD*
Age (Years)	30.01	11.94	29.80	10.97
Body height (cm)	164.98**	6.55	154.12	5.91
Body weight (kg)	62.73**	9.24	50.80	6.68
BMI (kg/m^2)	23.05**	3.16	21.41	2.74
FVC (L)	3.28**	0.56	2.22	0.43
FEV_1 (L)	2.87**	0.57	1.90	0.43
FEV_1/FVC (%)	87.31**	8.64	85.15	9.21
PEF (L/s)	7.20**	1.79	5.14	1.50
$FEF_{25-75\%}$ (L/s)	3.29**	1.08	1.96	0.70

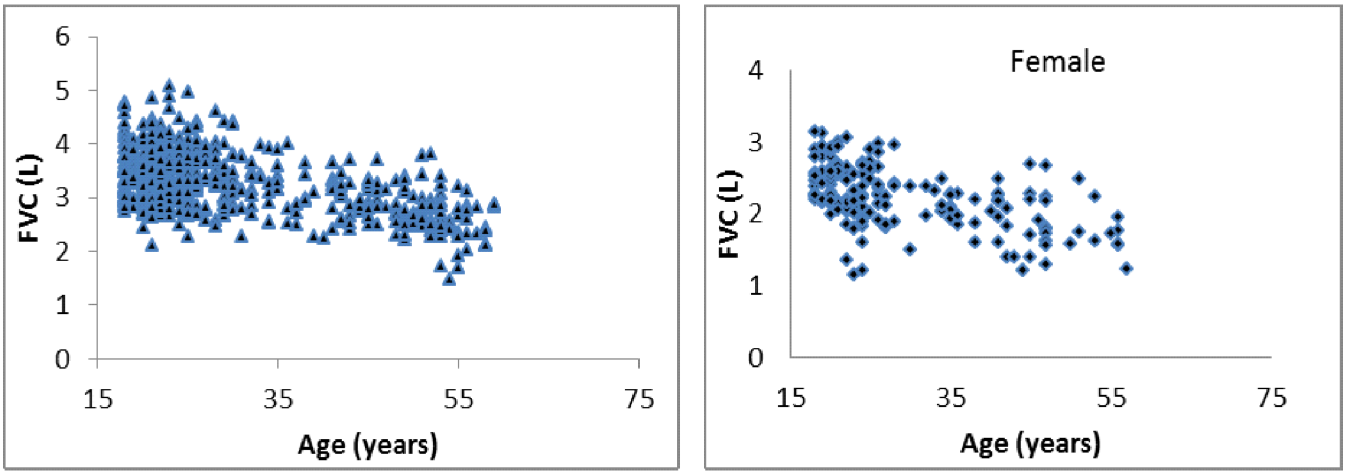
**=p<0.001

Relation of spirometry parametres with age and body height

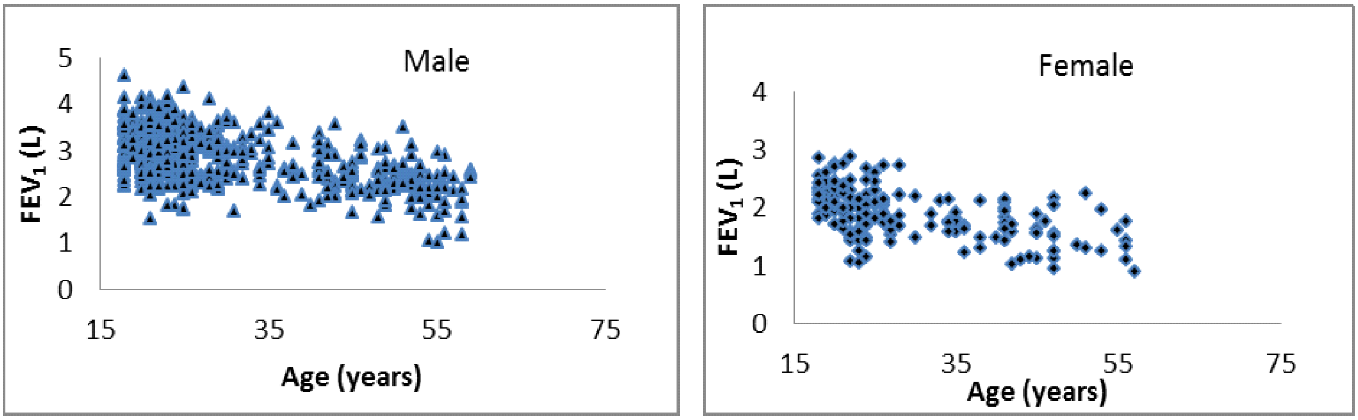
The relation of FVC, FEV_1, and PEF with age for male and female are shown in Fig. 1 through scattered plots. It is revealed that age has negative relationship with all spirometry parameters with age for both genders. Maximum negative correlation ($r = -0.55$) was observed in FEV_1 for male volunteers. However, minimum ($r = -0.31$) was found in PEF for male. Similarly, the relations of body height with the measured spirometry parameters are presented in Fig. 2. It was observed that body height was found positive correlation with FVC, FEV_1, and PEF. The maximum and minimum correlation coefficients were found for FVC and PEF respectively.

Prediction equation

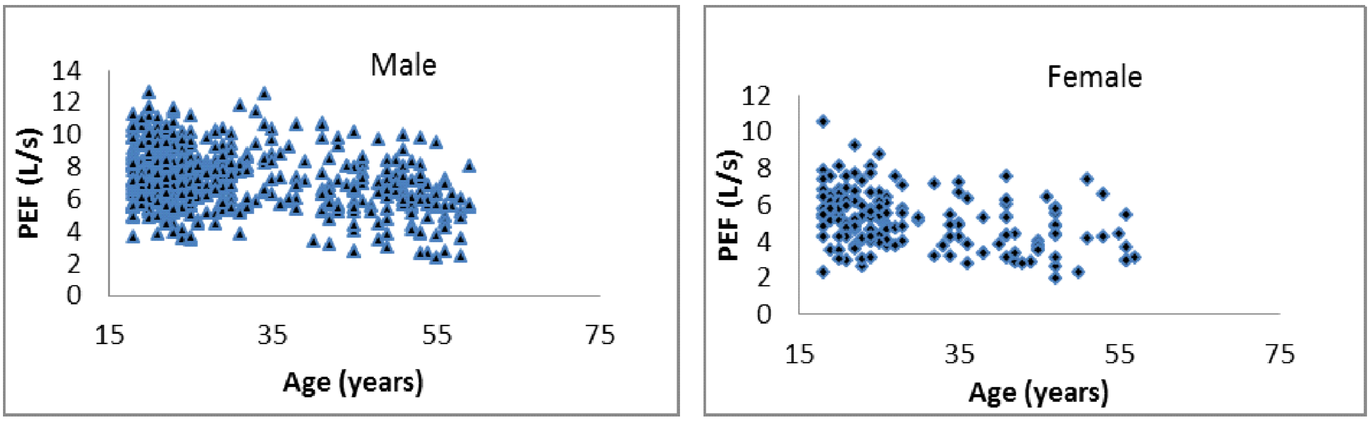
Linear multiple regression models for FVC, FEV_1 and PEF were developed for male and female separately and presented in Table II. The age and body height were taken as independent variables which had the significant influence on spirometry parameters as per VIP analysis. It was observed that all the regretted models were highly significant which clearly indicated



Age-weighted trend of FVC

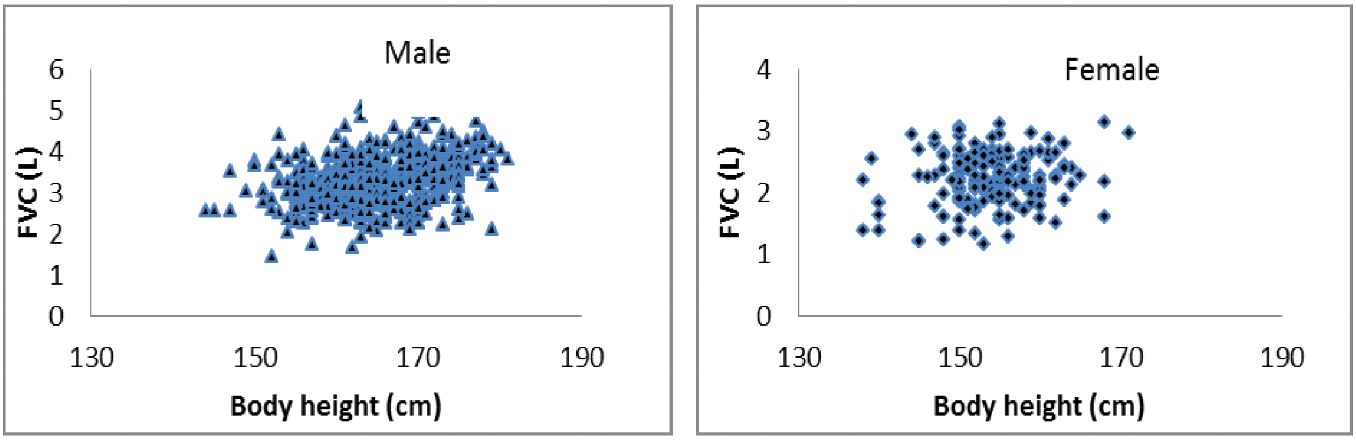


Age-weighted trend of FEV_1

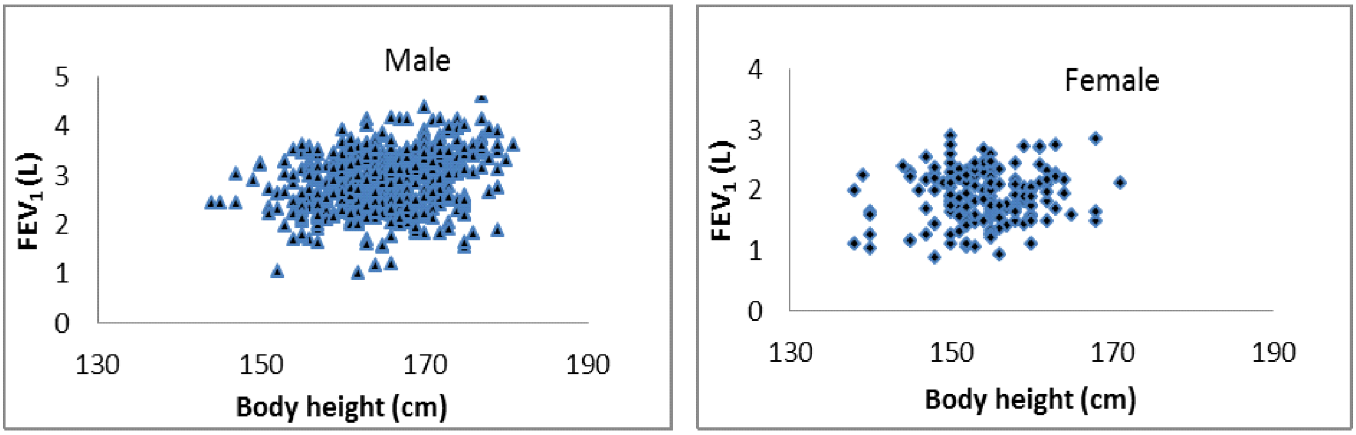


Age-weighted trend of PEF

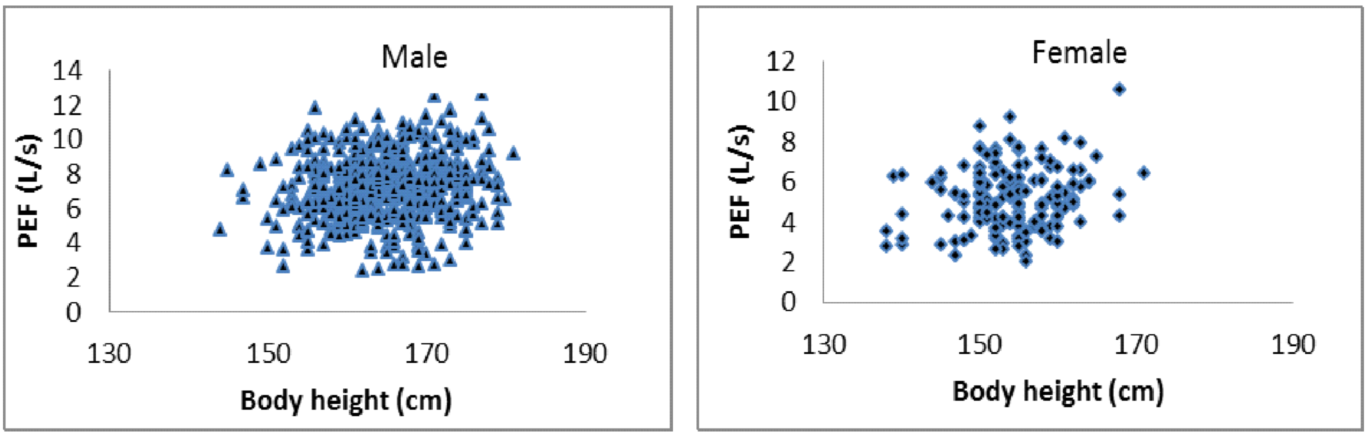
Fig. 1 : Scatter-plot of age-weight with spirometry parameters in both gender.



Body height-weighted trend of FVC



Body height-weighted trend of FEV_1



Body height-weighted trend of PEF

Fig. 2 : Scatter-plot of body height with spirometry parameters in both gender.

TABLE II : Regression equation of spirometry parameters for male and female.

Gender	*Parameter*	*Equation*	*SEE*	*Adj. R^2*
Males	FVC	-0.024 × A + 0.024 × H + 0.003	0.448	0.365
	FEV_1	-0.025 × A + 0.020 × H + 0.269	0.460	0.350
	PEF	-0.044 × A + 0.033 × H + 3.052	1.69	0.105
Females	FVC	-0.021 × A + 0.014 × H + 0.687	0.359	0.306
	FEV_1	-0.021 × A + 0.011 × H + 0.770	0.356	0.314
	PEF	-0.049 × A + 0.048 × H – 0.726	1.381	0.155

the significance of constant, coefficients of age and body height in the model. Further, coefficient of determination (R^2) and standard errors estimate (SEE) were also calculated and indicated against the each developed model in the Table. The SEE for FVC and FEV_1 of male and female were found in the range of 0.356-0.460 which clearly indicated the accuracy of the model development. The R^2 for FVC, FEV_1 and PEF were found 0.367 0.352 and 0.108 for male, however for female 0.315, 0.322 and 0.166, respectively.

Validation and comparison of models

The developed models of FVC, FEV_1 and PEF were cross validated by comparing the predicted values with the measured values in terms of significance (p-value), root mean square error (RMSE) and bias percentage which are presented in Table III. It was observed that the measured and predicated values of were non-significant (p>0.05) for all the developed models and it was found FVC and FEV_1 were in acceptable range of RMSE (1.27 to 2.13%) and Bias (0.42 to 5.57%). Hence the developed models can be used for predicting the reference values of FVC, FEV_1 and PEF for northeastern region. Further, the suitability of other similar models developed for Eastern, Western, Northern and southern India was checked by comparing the predicted values with the measured values. The comparative indicators such as mean difference, significance level, RMSE and Bias percentage is presented in Table III. The mean difference of FVC and FEV_1 were varied from -0.7 to -0.09 L which were statistically highly significant (P<0.001). The PEF predicted model was compared only with Western and Northern region of India. The mean difference of PEF was varied from -1.7 to -0.09 L/s, which were statistically highly significant except the female of Northern region of India. The minimum RMSE and Bias percentage was also 2.11 for female and -10.09 for male in FEV_1, respectively.

Discussion

The present study grants prediction equation for spirometry parameters such as FVC, FEV_1 and PEF for both males and females of Northeastern region in India. Here, linear regression models were developed and compared with other regions prediction equations in India. All the spirometry parameter significantly higher in male compared to female volunteers. It was also observed that age has negative relationship where height was positive correlation with all spirometry parameters for both the gender. Similar result was reported by Chhabra (5) and Dasgupta (3). Wu (13) was also reported that spirometry parameters such as FVC and FEV_1 were strong and significant association with age and height in both genders. Aging is associated with a decline in pulmonary functions (14, 15 and 16). The mean value of FVC of male volunteers was found 3.28 L which is 11.6, 20.2, 19.4 and 7.1% lower than the published value of Eastern, Western, Northern and Southern parts of India, respectively. Further, FEV_1 was also found 5.3 to 21% lower than other parts of Indian population. Chhabra (7) observed that the difference in interpretation between northern and eastern equations was 4.9% and between western and southern equations was 1.3% under 40 year age group. The mean value of PEF of male volunteers was found 7.2 L/s which are 14.7 and 10.1% lower than the published value of Western (4) and Northern (5) parts of India. Similarly, the FVC and FEV_1 for female of this region are also lower than the other parts of the country (3, 4, 5 and 6). This is because of the average body height of the northeastern people is lower than all other regions of the country. Chhabra (7) reported that the differences of FVC in shorter height volunteers were lower range of FVC where difference in magnitude and direction from those in taller volunteers with higher values of FVC but the trends of differences and their relationship of mean values were not cleared it may be biological or technical. Further, it was revealed that middle age group (21-40 years) volunteers were higher FVC (2 to 5 L) and FEV_1 (1.5-4.5 L) compared to other age groups. Nag

TABLE III : Validation of the developed models and comparison with other models.

	Northeastern		*Eastern Dasgupta*[3)]	*Southern Vijayan*[6)]	*Western Rao*[4)]	*Northern Chabbra*[5)]
	Observed values	*Present Prediction*				
Sub. No	M=544 F=167	M=544 F=167	M=491 F=128	M=130 F=117	M=739 F=132	M=489 F=196
Age, yr	18–60	18–60	15–69	15–40	15–55	18–65
			FVC (L)			
Male	3.28±0.6	3.24±0.3	3.7±0.4**	3.4±0.4**	3.7±0.6**	3.8±0.4**
Mean difference	0.04	–0.4	–0.09	–0.5	–0.5	
95% CI	–0.01, 0.09	–0.5, –0.4	–0.1, –0.03	–0.5, –0.4	–0.6, –0.5	
Bias%	3.51	–46.79	–11.37	–49.29	–55.92	
RMSE%	2.04	4.7	3.76	5.93	6.09	
Female	2.22±0.4	2.21±0.2	2.9±0.2**	2.5±0.2**	2.9±0.4**	2.7±0.2**
Mean difference	0.004	–0.6	–0.3	–0.7	–0.4	
95% CI	–0.07,–0.07	–0.7, –0.6	–0.4, –0.2	–0.8, –0.6	–0.5, –0.4	
Bias%	0.42	–64.88	–28.80	–68.49	–44.57	
RMSE%	1.27	5.50	2.77	8.97	3.62	
			FEV1 (L)			
Male	2.87±0.6	2.82±0.3	3.1±0.4**	3.0±0.4**	3.1±0.6**	3.2±0.4**
Mean difference	0.05	–0.3	–0.1	–0.2	–0.3	
95% CI	–0.006, 0.1	–0.3,–0.2	–0.2, –0.04	–0.3, –0.2	–0.4, –0.3	
Bias%	4.97	–27.26	–10.09	–22.41	–31.88	
RMSE%	2.13	2.93	2.84	3.55	3.40	
Female	1.89±0.4	1.84±0.2	2.5±0.2**	2.1±0.3**	2.5±0.3**	2.2±0.3**
Mean difference	–0.05	–0.6	–0.2	–0.6	–0.4	
95% CI	–0.02, 0.1	–0.6,–0.5	–0.3, –0.1	–0.7, –0.5	–0.4, –0.3	
Bias%	5.57	–57.64	–21.17	–63.81	–34.91	
RMSE%	1.27	4.59	2.31	5.55	2.63	
			PEF (L/s)			
Male	7.20±0.6	7.18±0.3	–	–	8.0±0.5**	7.7±0.7**
Mean difference	0.02	–	–	–0.8	–0.5	
95% CI	–0.1, 0.2			–1.0, –0.7	–0.7, –0.4	
Bias%	–0.69	–	–	–93.78	–53.20	
RMSE%	29.11	–	–	40.92	32.67	
Female	5.14±1.5	5.21±0.6	–	–	6.9±0.4**	5.24±0.5
Mean difference	–0.07	–	–	–1.7	–0.09	
95% CI	–0.3, 0.2			–1.9, –1.5	–0.3, –0.1	
Bias%	–7.08	–	–	–174.48	–9.92	
RMSE%	18.78	–	–	56.83	21.93	

**=p<0.001

(17) also reported that higher FVC (2-6 L) and FEV_1 (1.5-5.5 L) for the middle age group (20-39 years). The R^2 for FVC, FEV_1 and PEF were found 0.367, 0.352 and 0.108 for male, however for female 0.315, 0.322 and 0.166, respectively. Similar value of SEE and R^2 were reported by Dasgupta (3), and slightly higher by other researchers (3, 4, 5 and 6). The mean difference of FVC and FEV_1 were statistically highly significant ($P<0.001$) with comparison of present prediction equation which varied from -0.7 to -0.09 L. Hence, the result clearly indicated that the normal value of spirometry parameters can be predicted using the developed models of the study only which cannot be predicted by the equations developed for other regions of the country.

Limitations of the study

The limitations of the study are as follows:

1. Subjects were selected from a single profession of teaching-learning process.
2. Suitability of non-linear regression models for spirometry prediction not tested in the study.

Conclusions

The normal prediction equations of FVC, FEV_1 and PEF of northeastern populations of India were found significantly lower than that of other parts of India. The regression models developed for spirometry parameters for the other regions of India were not found suitable for this region. Hence, regression models were developed for predicting the normal FVC, FEV_1 and PEF for the northeastern region. The developed regression models were validated statistically and found suitable which can be used in both epidemiological studies and clinical aspects. Further, normal values of spirometry parameters of this region will also be very useful for finding the obstructive and restrictive lung diseases.

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