ORIGINAL ARTICLE

Comparison of Regression Equations For Predicted Values of Pulmonary Function Parameters In North Indian Subjects

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Abstract

Pulmonary function parameters are the most important and widely used exploratory tool in respiratory disorders. Most of the studies on these parameters describe lung capacities and flow rates in terms of absolute values. There are various equations to derive the predicted values of these parameters. Most of these equations are framed for Caucasian, American or Africans, but are frequently used in Indian subjects. There are very few equations for Indian subjects, which are also region specific. Hence, the present study was undertaken to compare the various regression equations for calculating predicted parameters in North Indian subjects. We used eight regression equations which are frequently used for calculating predicted values. The data of 75 Indian healthy subjects was used in these equations for comparison. The regression equations provided predicted value of pulmonary function parameters which varied markedly (0.24-123%) based on type of regression formula used. The closet seems to be Chatterjee and Vijayan equation. The anthropometric variable used in these equations can have a lot of bearing on the predicted values. However, based on literature and our experience of using eight regression equations, we found that none of these is perfectly suited for North Indian subjects.

Key Words

Regression Equation, Predicted Pulmonary Function, North Indian

Introduction

Pulmonary function tests (PFT) are the most important and widely used exploratory tool in respiratory disorders. They have assumed a key role in clinical diagnosis and epidemiological studies of respiratory disorders. Spirometry appears to be simple and inexpensive method to measure lung capacities and flow rates. Typical changes in major pulmonary function parameters like FEV1, FVC, FEV1% and PEFR can indicate the type of respiratory pathology and the extent of severity (1,2). Most of the studies on these parameters describe these capacities and flow rates in terms of absolute values. However, the anthropometric parameters like age, height, body weight and body surface area affect the various lung capacities and flow rates. The effect of these variables can be variable in different ethnic groups. The predicted values based on these anthropometric variables and ethnic group have been derived worldwide using various regression equations (3,4). Percentage predicted value of these parameters is considered to be better indicator of respiratory abnormalities as these are based on anthropometric variables and ethnic groups. The regression equations which can be used are available in large numbers and there are various claims for the accuracy of these predictions. Some studies do report the predicted values of these parameters. Most of these equations are framed for Caucasian, American or Africans, but are frequently used in Indian subjects. However, the lung volumes are much higher in Europeans and Americans as compared to Indians (5).

Earlier studies have reported the use of these for Indian subjects and some of them introduced a correction factors as the built of the body is very different in these various ethnic groups from Indians. There are very few studies which reported use of regression equation which were appropriate for Indian subjects. However, none of the studies found a suitable regression equation for North Indian subjects. Lung function in Indian shows regional and ethnic variation. Lung functions of North Indian and

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Eastern Indians were reported to be higher than South Indians (6,7). Hence, this study was planned to compare the various regression equations for predicted values of PFT in North Indian subjects.

Materials and Methods

There was extensive database search using pubmed, Indmed and google scholar to find out the various equations for calculating predicted values of PFT. There were 70 equations being used for calculating predicted values. The various regression equations were analysed for inclusion in the study. We selected eight equations which have been very frequently used to assess predictive values of PFT. (8-18) These equations included: Hankinson 1999 "NHANES III"; Crapo 1981; Knudson 1983, Chatterjee 1988; Vijayan 1990; Rao 1992, Gnanou 2011 and Memon 2007. These have been used in various ethnic groups (*Table 1*) including Asian, Indians and other ethnicities (6-10). The predictive values for the data of PFT for a group of 75 North Indian healthy subjects were calculated. Subjects who were smokers or on any medication, who were suffering from respiratory disorders or suffering from cardiac diseases or who had chest deformity or who have undergone recent eye surgery, abdominal or thoracic surgical procedures or who had history of syncope associated with forced exhalation were excluded from the study.

The data of subjects included height, weight and body surface area (BSA) which affects the lung function parameters hence, these were measured. Body height was noted in standing upright position without shoes in centimeters (cms). Body weight was measured in kilograms (Kgs) and body surface area (BSA) was calculated (6,11).

Pulmonary function parameters were measured using spirometry with the help of a computerized autospirometer (Helios 701:Chandigarh). All the subjects were thoroughly acquainted with the apparatus and were explained the maneuvers to perform the tests as per standard guidelines. The tests were carried out in standing posture. A nose clip was attached to the subject and a clean mouth piece was inserted into the breathing tube. It was made sure that there was no air leakage around the mouth piece and nose. Subject was asked to inspire maximally and to put in his best efforts during expirations as well (12). In the procedure 1, subjects were asked to inspire maximally from end expiratory position and then to place mouthpiece firmly in mouth and was asked to expire as hard, deep, rapid and completely as possible and then remove mouth piece. The most important values from this test include: Forced Vital Capacity (FVC) (L), Forced Expiratory Volume in 1sec (FEV1)(L), Peak Expiratory Flow Rate (PEFR) (L/sec), Forced Expiratory Flow 25-75%(L/sec). After rest of 5 minutes, subject was asked to breathe as rapidly and deeply as possible in and from the mouth piece for 15 seconds (procedure 2). This provided measurement of maximum voluntary ventilation (MVV) (5-13). The FEV1/FVC ratio was calculated, which is considered to be gold standard for diagnosing obstructive disorders. Predicted and percentage predicted values were derived for FEV1, FVC, FEV1% and FEF25-75%, FEF0.2-1.2, PEFR and MVV using regression equations for male and female subjects (*Table 2*). This was followed by calculation of percentage predictive values for these parameters (3,5,14,15).

Statistical Analysis was done using independent student's' test. $P<0.05$ was considered as statistically significant. Pearson's correlation coefficient was used for assessing relationship between anthropometric parameters and various predicted values.

Results

Males compromised 87% of the subjects. All these subjects were in age range of 19-58 years. The mean age was 33 years. Various lung volumes and capacities recorded by autospirometery were within normal range. FVC, FEV1, PEFR and MVV were significantly less in females. Percentage predicted values of FVC and FEV1 were within normal range. The values of all the parameters in females were lower as compared to males. There was a lot of difference in predicted and percentage predicted values for the parameters in Indian subjects using 8 regression equations. The equations were usually calculated based on age, height and weight as given in *table 2*. The equation used for Asians, Malaysians and Pakistani gave values closer to equation used in this study i.e. equation used for Eastern Indians for males and South Indians for females. These two equations used in the current study gave very similar results. The variation is huge in some equations i.e. equation used for European, Americans and Asians. In females predicted values were lower than males and the trend was similar to absolute values. The similar results were obtained when the equation were applied on the values of a 30 years male with height 170cmm and 30 years female with height of 165 cms (*Table 3*). There was negative correlation of age with predicted and % predicted values of FEV1 and FVC i.e. there is significant decrease in FEV1 and FVC with increase in age (*Table 4*). The negative correlation between age and other flow rates was significant. However, there was positive correlation between all anthropometric variables and FVC and FEV1 in the equation used for Europeans. Height had similar negative

Table 1. Selected Prediction Equations Used in Current Study

Equations	Parameters	Males	Females	Ethnic group for which equation developed
Knudson et al, 1983	FVC	0.0844H-0.0298A-8.782	0.044H-0.0169A-3.195	European
	FEV_1	0.0665H-0.0292A-6.515	0.0665H-0.0292A-6.515	
Hankinson et al, 1999 (NHANES)	FVC	$-0.1933+0.0064A-0.000269A^2+0.00018642H^2$	$-0.3560+0.01870xA-0.000382A^2+0.00014815H^2$	American
	FEV_1	$0.5536-0.01303A-0.000172A^2+0.00014098H^2$	$0.4333-0.00361A-0.000194A^2+0.0001196H^2$	
Crapo et al, 1981	FVC	0.0600H-0.0214A-4.650	0.0491H-0.0216A-3.590	Asian
	FEV_1	0.0414H-0.0244A-2.190	0.0342H-0.0255A-1.578	
Chatterjee et al, 1988	FVC	-0.0600H-0.0214A-4.650	No equation	Eastern Indian
	FEV_1	0.0414H-0.0244A-2.190	No equation	
Vijayan et al, 1990	FVC	[-6.877]+[0.062xH]	[-2.883]+[0.035xH]	South Indian
	FEV_1	$[-6.195]+[0.057xH]+[-0.0023xA^2]$	[-1.90]+[0.026xH]	
Rao et al, 1992	FVC	-0.036A+0.042H+0.03W-3.98	0.024A+0.024H+0.03W-3.03	Gujaratis
	FEV_1	-0.045A+0.043H+0.0l4W-3.53	-0.025A+0.020H+0.02W-0.82	
Gnanou et al, 2011	FVC	-2.176-0.027A+3.889H	-1.147-0.018A+2.695H	Malaysian
	FEV_1	-1.284-0.027A+3.167H	-0.643-0.02A+2.265H	
Memon et al, 2007	FVC	-0.848+[0.032xH]+[-0.020xA]	-3.072+[0.042 x H]+[-0.020xA]	Pakistani
	FEV_1	-1.440+[0.030xH]+[-0.020xA]	-1.866+[0.032xH]+[-0.019xA]	

A-Age, H-Height

Table 2. Predicted Pulmonary Function Parameters Calculated in 75 Subjects Using Various Regression Equations

Equation	Gender	FVC	% Difference	FEV1	% Difference
Knudson et al, 1983	Male	6.60 (47.94)	63	5.8 (47.81)	69
	Female	4.78 (50.91)*	80	4.94* (41.64)	123
Hankinson et al, 1999	Male	4.68 (67.3)	16	4.02 (68.69)	17
(NHANES)	Female	2.38 (105.34)	11	3.12 (58.0)*	41
Crapo et al, 1981	Male	4.85 (64.74)	20	4.04 (67.87)	18
	Female	3.49 (69.53)	31	3.03 (67.73)	36
Chatterjee et al, 1988	Male	4.05 (77.76)	0	3.43 (80.77)	0
	Female	-	-	-	-
Vijayan et al, 1990	Male	3.71 (85.35)	9	3.23 (85.90)	6
	Female	2.66* (91.16)	0	2.22* (92.47)	0
Rao et al, 1992	Male	4.06 (78.37)	0.24	6.74 (41.16)	97
	Female	1.65 (148.63)*	40	2.65 (68.19)*	19
Gnanou et al, 2011	Male	3.54 (88.82)	13	3.20 (85.81)	7
	Female	2.55 (94.85)	4	2.31* (88.75)	4
Memon et al, 2007	Male	3.93 (79.70)	3	2.99 (91.53)	12
	Female	2.95 (82.3)	11	2.76 (65.62)	24

Percentage difference as compared to Chatterjee et al (for males) and Vijayan et al (for females) used in this study

correlation with these parameters. BSA and weight had significant positive correlation with predicted and % predicted FEV1 and FVC.

Discussion

FVC and FEV1% are very important variables in distinguishing restrictive and obstructive lung diseases. A reduced FEV1% is considered to be hallmark of obstructive disorder. FEV1 is 80% of the FVC in normal healthy adults. Patients with obstructive lung disease have low flow rates as a result of high airway resistance therefore their FEV1% is low. In restrictive lung disease they have a reduced FVC but are able to achieve relatively high flow rates therefore their FEV1% exceeds 80% (3). In our study FEV1% was between 88-92% in

Table 3. Predicted values of FVC and FEV1 Calculated for 30 Years Old Male with a Height of 170 cm and 30 Years old Female with height of 165cm

Equation	Sex	FVC Predicted (% Predicted)	% Difference	FEV_1 Predicted (% Predicted)	% Difference
Knudson et al	Male	6.46 (56.8)	58	5.67 (58.6)	62
	Female	5.17 (47.0)	79	5.33 (42.9)	123
Hankinson et al	Male	4.76 (77.1)	16	4.08 (81.3)	16
	Female	2.77 (87.7)	4	3.41 (67.2)	43
Crapo et al	Male	4.91 (74.8)	20	4.11 (80.7)	17
	Female	3.85 (63.2)	33	3.3 (69.4)	38
Chatterjee et al	Male	4.1 (89.4)	0	3.51 (94.5)	0
	Female	-	-	-	-
Vijayan et al	Male	4.1 (89.4)	0	3.51 (94.5)	0
	Female	2.89 (84.0)	0	2.39 (95.8)	0
Rao et al	Male	3.79 (96.8)	8	6.76 (49.1)	93
	Female	1.8 (135)	38	2.79 (82.1)	17
Gnanou et al	Male	3.63 (101.2)	11	3.29 (100.9)	6
	Female	2.76 (88.1)	5	2.49 (91.8)	4
Memon et al	Male	3.99 (91.2)	3	3.06 (108.5)	13
	Female	3.26 (74.6)	13	3.09 (76.1)	29

Table 4 Correlation of Predicted Parameters with Anthropometric Variables

	Parameters	Age Male: Female	Height Male: Female	Weight Male: Female	BSA Male: Female
Knudson et al, 1983	FVC	0.35**: -0.07	0.35**: 0.88**	0.60**: 0.37	0.39**: 0.75**
	FEV_1	0.43**:-0.08	0.43**: 0.89**	0.60**: 0.36	0.37**: 0.75**
Hankinson et al, 1999 (NHANES)	FVC	-0.52**: 0.88**	-0.52**: 0.87**	0.37**: -0.34	0.43**: 0.16
	FEV_1	-0.61**:-0.77*	-0.61**:0.87**	0.32**:-0.20	0.41**: 0.31
Crapo et al, 1981	FVC	-0.47**:-0.76*	-0.47**: 0.95**	0.39**:-0.19	0.39**: 0.32
	FEV_1	-0.64**:-0.84**	-0.64**: 0.95**	0.29*:-0.29	0.43**: 0.22
Chatterjee et al, 1988	FVC	-0.52**:--	0.89**:--	0.37**:--	0.41**:--
	FEV_1	-0.61**:--	0.84**:--	0.31**:--	-0.61**:--
Vijayan et al, 1990	FVC	-0.08: 0.53*	1.00**: 1.00**	0.54**: 0.03	0.46**: 0.53
	FEV_1	-0.41**:0.53*	0.94**: 1.00**	0.43**:0.23	0.45**: 0.53
Rao et al, 1992	FVC	-0.46**:-0.44	-0.46**: 0.87**	0.68**: 0.38	0.51**: 0.77*
	FEV_1	0.52**:-0.64	0.52**: 0.91**	0.42**: 0.15	0.40**: 0.59
Gnanou et al, 2011	FVC	0.70**:-0.83*	-0.70**: 0.92**	0.25: -0.27	0.38**: 0.24
	FEV_1	-0.76**:-0.87**	-0.76**: 0.88**	0.20: -0.32	0.36**: 0.18
Memon et al, 2007	FVC	-0.66**:-0.77*	-0.66**: 0.95**	0.28: -0.21	0.39**: 0.30
	FEV_1	-0.68**:-0.80*	-0.68**: 0.93**	0.26: -0.24	0.39**: 0.27

*Values represent 'r' value of Pearson's correlation coefficient *P<0.05 significant correlation; **P<0.001 highly significant correlation A-Age, H-Height*

healthy subjects. The importance of percentage predictive values of pulmonary function parameters is more in classifying or diagnosing the type of respiratory disorder than the absolute values alone. The percentage predicted values compare the measured values in relation to a reference value for that specific population using anthropometric indices. The values less than 80% are considered to be indicative of obstructive type of respiratory disorders. Although some studies reported different cut off percentage. This decrease is considered to be a better indicator of obstructive type of respiratory disorders (3,12). This is further substantiated by the changes in MVV. MVV demonstrates all mechanical factors of breathing. Decrease in the value of MVV indicates increase in airway resistance, reduced compliance or decreased respiratory muscle force (2,12). The difference in pulmonary functions in male and females in this study is evident from the data and is in agreement with previous studies on pulmonary functions. (4,5) However, predicted and percentage predicted values vary markedly based on the type of equation used. The equation used in this study i.e. Chatterjee *et al* (14) and Vijayan *et al* (6) gave very similar results, indicating that Eastern and Southern Indians equations can be used for both ethnic groups. However, the equation used for Guajaratis showed a huge difference in calculated parameters. The Malaysian and Pakistani equation were also close to equation used in this study. These findings indicate that regional differences do exist in developing these equations. However, the equation used in different countries might provide similar results, if populations have similar build and anthropometric variables in those countries e.g. Malaysian and Pakistanis. This fact is also supported by correlation between various anthropometric variables and calculated parameters. The correlation values were close in above equations, but wide apart in equations used in Europeans and Americans. These anthropometric variables are used in developing these equations. Hence, these anthropometric variables play a very vital role in calculating predicted values (7,12). The regression equations should be very carefully chosen for calculating predicted values in Indian subjects. The % predicted values derived in our study by using 8 regression equations can label the same subject as normal or as having obstructive lung disease. In the present study percentage predicted values for FVC varied from 47 to 135 and for FEV1 from 43-109. A healthy subject can be classified as having obstructive respiratory disease of a person with decreased FEV1%, can be described as normal.

Gender wise distribution of various variables shows lesser values in female as compared to male subjects. This was consistent with all equations, but the decrease was very variable with different equations. These findings may be explained by the fact that there is greater development of musculo-skeletal system of the thoraco-abdominal compartments as well as that of the pulmonary tissue in men. The parameters like height, weight and body surface area of all subjects were comparable yet the factor attributed to lesser values in females in the present study could be differences in the outdoor and occupational habits and another factor could also be the possible effects of repeated pregnancies in these women (16). Differences in various parameters have been attributed to these anthropometric differences. BSA has been considered to be an independent variable for deriving spirometric predictions (7). There was decrease in FEV1 and FVC as age increases. The same negative correlation was found as height increases. Similar association has been reported in earlier studies in healthy volunteers (3). However BSA and weight had positive correlation with these parameters in healthy subjects.

Thus, we can conclude that a specific regression equation developed for North Indian subjects based on data of a large number of north Indian subjects is needed.

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