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Applicability of established regression equations in the prediction of peak expiratory flow rate in Indian adults

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Abstract:

BACKGROUND: Peak expiratory flow rate (PEFR) helps in the assessment of airflow limitation. Its relationship with age and height has been established in several previous studies with different sample size in different regions from India. A large-scale study (in 2014) established a set of regression equations with a national level reference regression equation.

AIM: The aim of this study was to check the applicability of established regression equations in the prediction of PEFR in apparently healthy young adults.

MATERIALS AND METHODS: A cross-sectional study was conducted with 104 young adults (males = 55, females = 49). PEFR (L/min) was measured using computerized spirometer. Established regression equations from the previous study were used to predict PEFR from the age and height of the participants. Measured PEFR values were compared with predicted values by the paired *t*-test with $\alpha = 0.05$. Further, the prediction was considered “comparable” if the value was $<\pm 10\%$ of the measured value.

RESULTS: Measured versus predicted mean PEFR (from regression equation established for adult Indian national) for male was 481.99 ± 63.52 L/min versus 496.04 ± 20.70 L/min ($P = 0.096$) and female was 365.19 ± 61.36 L/min versus 336.82 ± 13.78 L/min ($P < 0.001$). In male, 54.55% and in female, 44.90% was comparable prediction from regression equation established for Indian adult national.

CONCLUSION: Estimated PEFR in male showed fair comparable prediction and female showed poor comparable prediction. Further studies, including all Indian states with a large sample, may help in the establishment of more accurate prediction equations.

Keywords:

Asthma, regression analysis, respiration, respiratory function tests, spirometry

Introduction

Peak expiratory flow rate (PEFR) is a simple parameter to assess the airflow limitation with the minimal instrument.^[1] The test can be carried out on patients in any clinic or outdoor settings with little expertise from the instructor. It helps in the diagnosis and prognosis of patients suffering from asthma and chronic obstructive pulmonary disease.^[2,3]

The PEFR changes according to the change in age and height of the individual. Several previous studies from India have established regression equations for the estimation of PEFR from the age and height of the participants.^[4-9] These established equations are used to predict PEFR which is commonly used in spirometry report. It helps to get a fair knowledge about the comparison between obtained value and predicted value. Hence, widely accepted equations should be established for better prediction.

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In 2014, “PERFORM” study established regression equations for five different Indian cities (viz., Hyderabad, Jaipur, Kolkata, Pune, and Srinagar) and formulated a national level equation for prediction of PEFR.^[6] In that study, researchers used “Breathometer” device which is similar to the “Mini-Wright peak flow meter.” Authors used the device to measure PEFR at field level on a large sample with wide age distribution. However, field level measurement by peak flow meter may provide different result of PEFR than the laboratory-based spirometry during the recording of forced vital capacity (FVC).^[10]

With this background, this study was conducted to compare the measured PEFR by computerized laboratory-based spirometry and predicted PEFR from age and height of an individual calculated from regression equations. This comparison would give us further insight about applicability of the regression equations in prediction of PEFR measured along with FVC by computerized spirometer.

Materials and Methods

After obtaining clearance from the Institutional Ethics Committee, a cross-sectional study was conducted from March 2016 to April 2017 in the postgraduate Department of Physiology.

Minimum sample size estimation

The study was designed to compare the measured PEFR and predicted PEFR. Hence, we considered sample size calculation formula as: $N = [(1/q_1 + 1/q_2) S^2 (Z\alpha + Z\beta)^2] \div E^2$.

Where, N is total sample size, q_1 and q_2 denotes proportion of participants in each group (for this study, $q_1 = q_2 = 0.5$), S is expected standard deviation, $Z\alpha$ and $Z\beta$ denotes standard normal deviate for α and β , respectively, E is the effect size and is calculated as the difference between the expected mean of two groups.^[11,12]

For the mean PEFR, a previously published study from the same state was taken as reference. In that study, authors reported the mean PEFR for male as 469 ± 70 L/min and female as 365 ± 39 L/min.^[13] We expected that there would be 10% difference between the measured and estimated PEFR. With these data and $\alpha = 0.05$ and $\beta = 0.2$ (where $[1-\beta]$ denotes power of the study = 0.8 or 80%), the estimated total sample size for two groups for male was = 70 and female was = 36. Adding 20% (assuming dropout) to that value, estimated total sample size for male was = 84 and female was = 43 (43.2 to the nearest integer). According to the study design, we needed one group of participants (q_1) and data for the second group (q_2) would be calculated from the age and height of the first group of participants. Hence, the

final total sample for male was = 42 (84/2) and female was = 22 (43/2, to the nearest integer). However, we intended to include more participants according to the available time and workforce.

Participants

Apparently healthy male and female participants were recruited as a convenience sample for this study. Inclusion criteria were as follows: age >18 years (i.e., adult participants) and written consent for participation. Exclusion criteria were as follows: the presence of any chronic disease, suffering from any acute illness, and participants with any addiction. Participants were briefed about the aim of the study. Then, the whole procedure of the test was described verbally, and a video of the test was shown for growing a fair knowledge about the procedure of the test.

Variables and data collection

PEFR was measured by computerized spirometer FLOWHANDY ZAN 100 USB computerized spirometer (nSpire Health, Inc., Germany). The instrument uses the principle of “differential pressure with variable diaphragm” for measurement of air flow and uses a variable impedance pneumotach flow transducer. The accuracy of the instrument is + 2%, 0.05–15 L/s.^[14] Measurement was carried out at the same time of a day (between 10 a.m. and 11 a.m.) and environment (temperature 23°C, 50% humidity) for all participants. The video clip which was shown during the recruitment of participants was shown to participants again on the test day. A full demonstration of the procedure with the instrument was also shown by the data collector who measured their own PEFR in front of the subject. After this demonstration, PEFR was measured thrice on the participants. The maximum value was considered the final reading of PEFR and stored for further analysis.^[15]

Age of the participants was recorded in completed years. Standing height was measured in centimeters in nearest 0.1 cm on a portable stadiometer according to standard protocol.^[16] Age and height were used to predict PEFR in male and female participants according to the available regression equations for adult Indian nationals and regression equations for different Indian cities. The different Indian cities whose regression equations were used in this study are shown in Figure 1 and the regression equations are shown in Table 1.^[6]

Statistical methods

Data were expressed in the mean and standard deviation. Mean age, height, weight, body mass index (BMI), and PEFR in male and female were compared using the unpaired t -test. Mean measured PEFR and predicted PEFR separately in male and female group were compared by the paired t -test.

For over and underprediction of PEFR, $\geq \pm 10\%$ of the measured value was taken as the limit (i.e., if a predicted PEFR was $< \pm 10\%$ of measured value, the prediction was considered “comparable”). Number of over and underprediction of PEFR was expressed in percentage. For rating of the comparable prediction, the following scale was used: $< 50\%$ = Poor, $50\% - 59.99\%$ = Fair, $60\% - 69.99\%$ = Good, $70\% - 79.99\%$ = Very good, and $\geq 80\%$ = Excellent.

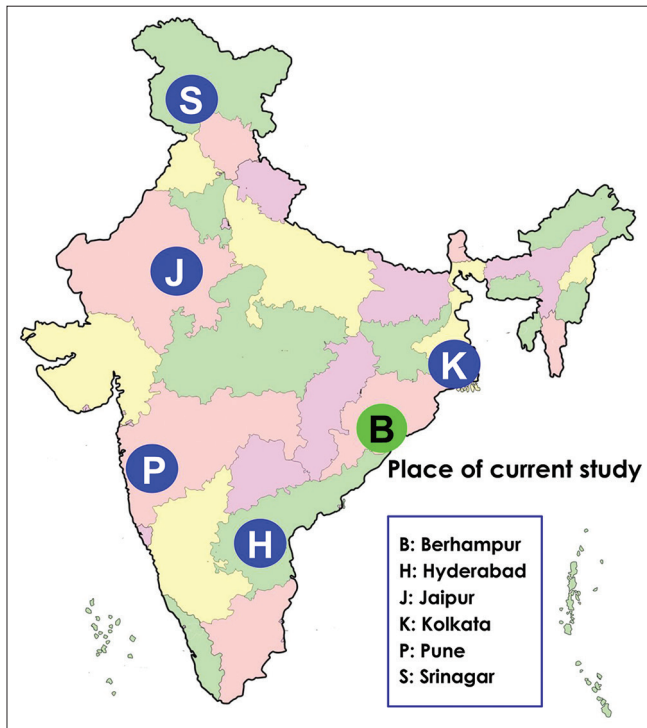


Figure 1: Different Indian cities for which regression equations were established in “PERFORM” study and the city of the current study in Indian map (Map and location of cities may not be accurate according to scale)

Residual (measured value – predicted value) PEFR was plotted against measured PEFR for visual representation of over and underprediction. A positive value of residual suggests underprediction and a negative residual suggests overprediction.

For all statistical analysis, the chance of Type I error (α) was set at 0.05. Statistical analyses were carried out in GraphPad prism version 6.01 (GraphPad Software, La Jolla, CA, USA) and OpenOffice™ Calc spreadsheet (The Apache Software Foundation, USA). In this study, a $P > 0.05$ indicates that the comparison between measured and predicted PEFR is not significantly different and the estimated PEFR from the corresponding regression equation is acceptable.

Results

A total 104 participants (male = 55 and female = 49) participated in the study. Mean age in male and female was 19.91 ± 1.43 years (minimum 18 years and maximum 24 years) and 19.24 ± 1.30 years (minimum 18 years and maximum 22 years), respectively. Sex-wise age (years), height (cm), weight (kg), and BMI (kg/m^2) are shown in Table 2.

Measured PEFR by computerized spirometry during FVC in the male was 481.99 ± 63.52 (L/min) and the female was 365.19 ± 61.36 (L/min). Predicted PEFR by national level regression equation in male was 496.04 ± 20.70 (L/min) (measured vs. predicted paired t -test $P = 0.096$) and female was 336.82 ± 13.78 (L/min) (measured vs. predicted paired t -test $P < 0.001$). Comparison of measured PEFR and predicted PEFR according to regression equations of different cities is shown in Table 3.

Table 1: Regression equations established by Kodgule et al. for the estimation of peak expiratory flow rate (L/min) from age and height of adult Indian participants

Regions	Regression equations for PEFR (L/min)	
	Male	Female
National	$-1.807 \times A + 3.206 \times H$	$-1.454 \times A + 2.368 \times H$
Hyderabad	$292.745 - 4.467 \times A + 1.830 \times H$	$404.621 - 4.583 \times A + 0.410 \times H$
Jaipur	$-134.573 - 2.178 \times A + 3.988 \times H$	$94.229 - 1.167 \times A + 1.474 \times H$
Kolkata	$104.761 - 2.430 \times A + 2.833 \times H$	$112.922 - 1.515 \times A + 1.822 \times H$
Pune	$-55.448 - 1.862 \times A + 3.525 \times H$	$-78.931 - 1.168 \times A + 2.829 \times H$
Srinagar	$190.393 - 2.115 \times A + 2.094 \times H$	$171.431 - 0.655 \times A + 1.160 \times H$

A=Age (years), H=Height (cm)

Table 2: Age, height, weight, and body mass index of study participants according to sex

Parameters	Mean $\pm$ SD (95% lower CI-95% upper CI)		P
	Male (n=55)	Female (n=49)	
Age (years)	19.93 ± 1.40 (19.55-20.31)	19.33 ± 1.18 (18.99-19.67)	0.021*
Height (cm)	165.95 ± 6.67 (164.15-167.76)	154.10 ± 5.61 (152.49-155.71)	$< 0.001^*$
Weight (kg)	67.83 ± 13.68 (64.13-71.52)	57.50 ± 11.51 (54.19-60.80)	$< 0.001^*$
BMI (kg/m^2)	24.50 ± 3.98 (23.42-25.58)	24.24 ± 4.82 (22.85-25.62)	0.760

*Statistically significant two-tail P value of unpaired t -test with $\alpha = 0.05$. BMI=Body mass index, SD=Standard deviation, CI=Confidence interval

The national level regression equation was able to predict PEFR optimally in 54.55% (30/55) of males and 44.90% (22/49) of females. Level of optimum, over, and underprediction of PEFR by regression equations are presented in Table 4. Residuals were calculated by subtracting measured PEFR (L/min) and predicted PEFR (L/min), and it was plotted in graphs against measured PEFR (L/min) and shown in Figure 2.

Discussion

The aim of this study was to test the applicability of regression equations in the prediction of PEFR from age and height of adult Indian participants. Regression equations are used to get relationship between two-related variables and are expressed in an equation with explanatory and dependent variable.^[17,18] It is well established that PEFR depends on the age and height of the subject. Several studies were conducted to find the regression equation for the prediction of PEFR in Indian population.^[6,19,20] However, due to wide geographical span, conduction of a pan-India single study is still lacking in the literature. Small scale and regional regression equations may fail to predict the PEFR for a population with approximately 2000 ethnic groups.^[21] The study conducted by Kodgule *et al.* was a large scale and recent study.^[6] It included five Indian cities to find the equations with a median Indian equation for adult participant [Table 1]. The study was cross-validated with a sample from these limited cities. Hence, we intended to find its relevancy in the prediction of PEFR in participants of a different city [Figure 1].

This study showed that the national level equation was able to predict the PEFR in male [Table 3] with a fair level of acceptance with 54.55% comparable

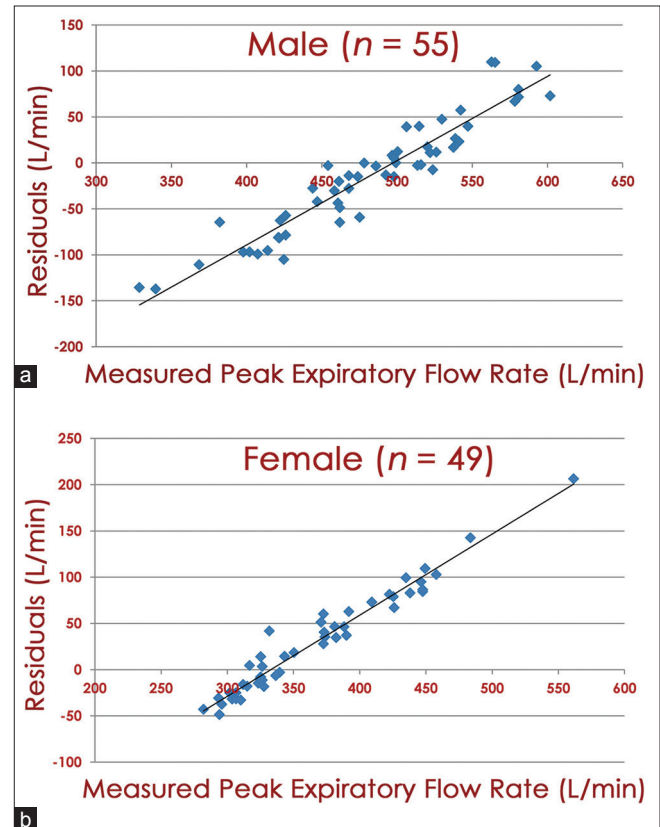


Figure 2: Scatter plot between residuals (the difference between the measured and predicted value from regression equation for adult Indian) and measured peak expiratory flow rate (L/min) in male (a) and female (b)

Table 3: Comparison of measured peak expiratory flow rate and predicted peak expiratory flow rate according to the regression equations

Sex	PEFR (L/min)						
	Measured	Estimated from regression equations established for					
		National	Hyderabad	Jaipur	Kolkata	Pune	Srinagar
		mean±SD, P					
Male (n=55)	481.99±63.52	496.04±20.70, 0.096	507.42±11.75, 0.004*	483.85±25.78, 0.825	526.48±18.08, <0.001*	492.43±22.80, 0.215	495.75±13.30, 0.104
Female (n=49)	365.19±61.36	336.82±13.78, <0.001*	379.23±6.35, 0.102	298.82±8.69, <0.001*	364.42±10.77, 0.923	334.46±16.24, <0.001*	337.53±6.73, 0.002*

*Statistically significant two-tail P value of paired t-test with $\alpha=0.05$. PEFR=Peak expiratory flow rate, SD=Standard deviation

Table 4: Number of comparable, over, and underprediction of predicted peak expiratory flow rate by regression equations

Regions	Male (n=55), n (%)			Female (n=49), n (%)		
	Comparable prediction*	Overprediction	Underprediction	Comparable prediction*	Overprediction	Underprediction
National	30 (54.55)	17 (30.91)	8 (14.55)	22 (44.90)	7 (14.29)	20 (40.82)
Hyderabad	28 (50.91)	20 (36.36)	7 (12.73)	15 (30.61)	24 (48.98)	10 (20.41)
Jaipur	29 (52.73)	15 (27.27)	11 (20.0)	18 (36.73)	0	31 (63.27)
Kolkata	29 (52.73)	23 (41.82)	3 (5.45)	18 (36.73)	18 (36.73)	13 (26.53)
Pune	30 (54.55)	17 (30.91)	8 (14.55)	24 (48.98)	4 (8.16)	21 (42.86)
Srinagar	32 (58.18)	16 (29.09)	7 (12.73)	20 (40.82)	8 (16.33)	21 (42.86)

*If the difference between measured and predicted PEFR is below 10% of measured PEFR, it was considered comparable prediction. PEFR=Peak expiratory flow rate

prediction [Table 4]. In contrast, estimation in female was poor with 44.90% comparable prediction with a significant difference ($P < 0.0001$ in a paired t -test) in measured and predicted values [Table 3]. There may be multiple reasons for this result. First one may be the regression equation. The equation was formulated from the data collected from five cities which did not include the city of the current study. Second one may be the difference in the methodology of two studies. During the establishment of regression equation, the authors used a peak flow meter. However, in the current study, a computerized laboratory-based spirometer was used which record the PEFR from the FVC. Third one may be the study design. In the current study, several precautions were taken to get highly credible result. Participants were briefed about the study procedure and procedural video was shown twice to make them gain knowledge about the test. They were shown live demonstration of the test by the researcher to make them well acquainted with the instrument.

The nearest city from the city of the current study is Kolkata. When the regression equation of Kolkata was used, it also showed 52.73% (fair) optimum prediction in male and 36.73% (poor) in the female. However, the mean showed significant difference in male [$P < 0.001$, Table 3] and nonsignificance in female ($P = 0.923$). Other cities showed various level of over and underprediction [Table 4]. The obvious reason behind it may be a difference in the geographical area of the study.

It was observed that no equation was able to score even good level (60%–60.99%) of prediction [Table 4]. In male, all equations were able to score a “fair” level of estimation. All predictions in female showed consistently a “poor” level. The residual analysis also showed the higher level of residuals in female, especially under prediction [Figure 2]. To the best of our knowledge, no study ascertained the applicability of regression equation in prediction of PEFR in adult Indian population. Hence, it was not possible to compare the result of the current study with previous studies. Swaminathan *et al.* evaluated a set of regression equations in Indian children with a different level of over and underprediction. In that study, the author found the highest level of prediction as 55.6% in boys and 53.3% in girls.^[22] This result is almost similar to the result found for median Indian equation in the current study (54.55% for male and 44.90% for female) [Table 4]. Hence, the set of equation, as established by “PERFORM” study, in its current form may predict the PEFR (L/min) with various level of over and underprediction.

Regression equations are commonly used to provide reference values along with flow meters and spirometer.

This is the reason why near accurate equations should be used to provide a credible estimation of PEFR. This helps to get a valid comparison between the measured and predicted value in reference to the age and height of the participant. Hence, it is suggested to conduct further nationwide study to establish regression equations for the adult Indian population. These equations can be used by the manufacturer of the spirometer and flow meter.

Limitation of the study

There are several limitations of the study. The convenience sample, comprised medical students had a narrow age range. Medical students may have higher level of education than the general population. Hence, maybe the participants had understood the test procedure better than the general population. The same test in the general population may not be of that level successful. The state in which the study was conducted has a large geographical diversity. Participants from different cities of the state had participated in the study. However, we excluded participants domicile to other states. In most of the studies, the researchers used a peak flow meter to measure/record the PEFR during the establishment of regression equations. In contrast, a computerized spirometer was used in the current study.

Conclusion

The regression equations established in the “PERFORM” study may provide various level of overestimation or underestimation in PEFR (L/min) in healthy young adults. A fair level of estimation in male and poor level of estimation in female may be expected. Further studies with a large nationwide sample would help in establishment of more acceptable regression equations for the prediction of PEFR (L/min) for the adult Indian population.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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