Original Article

Evaluating the Suitability of Prediction Equations for Lung Function in Indian Children: A Practical Approach

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Objective: *Although several prediction equations to evaluate peak expiratory flow rate (PEFR) of Indian children are available in literature, clinicians and researchers need to make a logical choice of which equation to use as reference. The aim was to demonstrate a practical approach to making such a logical choice by using prediction equations on our study population.* ***Methods****: Eighteen linear regression equations generated on Indian children were chosen from available literature. PEFR measured on a Wright peak flow meter on 81 boys and 60 girls, aged between 8 and 13 years, was compared with the predicted values obtained from the equations. Data was systematically analyzed for the extent of over-estimation and under-estimation, correlation between the predicted and measured values and bias and limits of agreement using Bland-Altman plots.* ***Results:*** *The correlation between observed and predicted values using the eighteen equations ranged between 0.616 and 0.797 (for all P<0.001). The Bland-Altman plots indicated that for all but three equations in boys and three equations in girls, lower measured values of PEFR were associated with higher predicted values. A final choice of a "reference" prediction equation was based on a combination of factors which included a high correlation between actual and predicted PEFR values, the "bias" of the estimate, the "limits of agreement" and the extent to which equations over or under-estimated PEFR.* **Conclusion***: A practical approach to evaluate the applicability of prediction equations on an independent data set has been demonstrated.*

Key words: *Bland-Altman plot, Peak expiratory flow rate, Prediction equations.*

ALTHOUGH pulmonary function tests using complete spirometry provide quantifiable measures of the state of the respiratory system and useful information for the management of respiratory tract illnesses in pediatric practice, instrumentation for this is relatively expensive and only available in hospitals. In contrast, peak expiratory flow rate (PEFR) can be measured using relatively inexpensive peak flow meters and are of value in identifying and assessing the degree of airflow limitation of individuals.

The clinical use of PEFR requires a comparison with normative/standard data, *e.g.* for asthma, flow limitation is diagnosed objectively if PEFR is less than 80% of the "normal" or reference value. PEFR can thus be used to assess the presence and severity of airflow obstruction and the response to therapy.

The American Thoracic Society (ATS) has recommended that laboratories should use the published reference equations (based on cross-sectional data) that most closely describe the populations tested in their laboratories and suggest that laboratories make an empirical assessment of how different equations relate to measurements made in 20 to 40 healthy subjects typical of the laboratory's clientele(1). A large number of sources for reference data of PEFR in children exist in India in the form of prediction regression equations. This poses a problem for clinicians and researchers about which equation to use for normative data from the many that are available. This paper addresses two issues. First, it provides comprehensive data of regression equations that have been described in published literature to predict PEFR in Indian children. In this context we were particularly interested in sample size, validation of the published equations and the extent of variance in PEFR accounted for by the predictor variables. Second, it compares independently measured PEFR in South Indian rural children ("actual" measures) with "predicted" measures using all the prediction equations we reviewed. The aim of this exercise was to determine which equation was most suitable for an independently generated data set and to demonstrate a practical approach to making such a logical choice.

Subjects and Methods

The data set used for this analysis included healthy children aged between 8-13 years, who were clinically free from respiratory diseases and with no prior history of asthma. The regression equations were all tested for a sample that was within the age range for which the equation had been generated. This group of one hundred and forty one children, (81 boys and 60 girls) was recruited from three schools of Palamaner, Chittoor district, Andhra Pradesh, a largely rural area.

Height was measured to the nearest 0.2 cm and weight to the nearest 0.5 kg with light clothing. PEFR was measured using a mini Wright peak flow meter with the child standing. The highest of three values (L/min) was used in the analysis and was compared with the predicted value obtained in eighteen prediction equations. The eighteen equations were chosen by reviewing published literature obtained through both a pubmed search and a manual search of documents. Studies from papers published prior to the year 1975 were excluded from the analysis. In addition, equations obtained from studies on children living in tribal regions and in high altitudes were excluded.

PEFR was measured after all subjects assented to the study. The data were collected as part of a school health evaluation program following consultations with the teachers and administrators. Ethical approval was obtained as part of a larger survey in the area.

Statistical analysis

Comparison between the measured values and the predicted values obtained from the 18 equations were analyzed to ascertain the degree of over-estimation and under-estimation (that is, above or below 10% of predicted value), and the extent of correlation between them. Bland-Altman plots (scatter plots of the difference between predicted and measured PEFRs versus the average of the predicted and measured PEFRs) were constructed to measure agreement between measured values and the predicted values from the 18 equations for boys and girls separately, and the bias and limits of agreement were calculated(2,3). The mean difference between the predicted and the measured PEFR value is the estimated bias, while the mean difference plus or minus 1.96 standard deviations indicates the limits of agreement, that is, how far apart measurements by the two methods were likely to be for most individuals. Correlation of the difference in PEFR versus the mean PEFR for each equation was obtained.

Results

Characteristics of 18 described equations are described in *Table I*(4-17). The mean heights and weight and measured PEFR of the children are indicated in *Table II.* The mean PEFR of boys was higher than in girls even after adjusting for height, although not significant [boys 302 L/min (CI: 292.5 -312.0) versus girls 291 L/min (CI: 279.8 -302.9)].

The values obtained using each of the 18 sets of equations published was compared with the actual measured PEFR of the 81 boys and 60 girls. Based on the American Thoracic Society requirement for a 10% accuracy in peak expiratory flow measurements to account for the higher within-and between-subject variability associated with PEF measurements and because of testing instrument limitations(18), the percentage of comparable values (within 10% of predicted), the percentage of over-estimation and under-estimation of values using the prediction equations was calculated. *Tables III* & *IV* provide the extent of under-estimation and over-estimation using these equations and also indicate the correlation of predicted values with the measured PEFR.

The percentage of "comparable" (*i.e.,* within 10% of predicted) values ranged from 5% to 54.6% for all children across equations, with a range of 1.2% to 55.6% in boys and 3.3% to 53.3% in girls. Equation 4 had the highest percentage of comparable values for all children as a whole and when separated by gender. Among boys, equations 3,4,8 and 15 and among girls, equations 4 and 15 had more than 50% of the values within the comparable range. The degree of over-estimation ranged from 1.4% to 46.1% for all children with a range of 0% to 75.3% in boys and 1.7% to 45.0% in girls. The degree of under-estimation ranged from 9.2 % to 93.6 % for all children with a range of 0% to 97.5 in boys and 5% to 93.3% in girls. Equation 1 and 6 consistently underestimated PEFR values in all children. For boys, over-estimation using Equation 10 was high (75.3%). Equation 6 underestimated most values in girls. For boys, in addition, the degree of under-estimation using Equation 7 was very high (97.5 %).

The correlation between the measured PEFR and the predicted values was moderately high with correlation coefficients above 0.7 for all equations, except equation 16 in boys and for 14 (out of 16) equations in girls. For boys the highest correlation was obtained using equation 3, while equation 13 had the highest correlation in girls. However, correlation coefficients only show the strength of the relationship, but not the agreement between the two values. Data which seem to be in poor agreement can also show very high correlations(2).

The Bland-Altman plot (*Figs. 1* & *2*) was used to further measure the agreement of the values obtained from the prediction equations with measured PEFR. A highly significant negative correlation of varying magnitude was obtained between the difference (predicted - measured) and the mean (average of predicted and measured) PEFR values with the exception of equations 1, 10 and 18 for boys and equations 12, 15 and 17 in girls. These data suggest that the majority of equations overestimated PEFR at low mean PEFRs while they underestimated PEFRs at higher mean PEFRs.

The mean bias ranged from 19.8L/min

TABLE I–*Description of Prediction Equations used in the Study*

Eqn. No.	Sour of data	Sample size	Equipment	Age	Equation	R value
1.	Vijayan, *et al*.,2000(4)	Total = 469 (Boys = 246, Girls = 223) Done in Chennai, South India	Dry rolling spirometer	7-19	Male: PEFR = (0.063* Height in cm)+ (0.061* Weight in kg) - 6.784 Female: PEFR = (0.20* Height in cm) + (0.070* Weight in kg) – 1.613	NA*
2.	Swaminathan, Venketesan and Mukunthan, 1993(5)	Total = 345 (Boys = 191, Girls = 154) Done in Chennai, South India	Mini Wright peak flow meter	4 - 15	Male: PEFR = (4.08* Height in cm) – 284.55 Female: PFER = (3.92* Height in cm) – 277.01	NA*
3.	Swaminathan, Venketesan and Mukunthan, 1993	Total = 345 (Boys = 191 Girls = 154) Done in Chennai, South India	Mini Wright peak flow meter	4 - 15	Male: PEFR = (2.04* Heigh in cm) + (4,78* age in years) + (2.73* Weight in kg) – 134.29. Female: PFER = (2.03* Height in cm) + (3.18* Age in years) + 2.71 Weight in kg) – 132.92	NA*
4.	Parmar, Kumar and Malik, 1977(6)	Total = 595 (Boys = 340 Girls = 255) Done in Chandigarh, North India	Wright's peak flow meter	6 - 16	Male: PEFR= (5.058* Height in cm) - 408.664 Female: PFER = (4.183* Height in cm) - 273.45	NA*
5.	Rajkapoor, Mahajan and Mahajan, 1997(7)	Total = 186 (Boys = 98 Girls = 88) Done in Rohtak, Haryana North India	Computerized spirometry	6 - 13	Male: PFER = (11.52* Age in years) + (88.99* Height in cm) + 10.44 Female: PFER = (4.14* Age in years) + (252.44* Height in cm) - 140.32	NA*
6.	Sharma, *et al*.,1997(8)	Total = 410 (Boys = 222 Girls = 188) Done in Delhi, North India	Portable elect-ronic lung function spirometer	10 - 15	Male: PEFR = (0.0278* Height in cm) + (0.1307* age in years) + (0.0233* Weight in kg) - 2.52 Female: PEFR = (0.2382* Age in years)+ (0.0299* Weight in kg) – 0.1716	Boys: $R^2 = 0.56$ (R= 0.748) Girls: $R^2 = 0.38$ (R= 0.616)
7.	Nair, *et al*., 1997(9)	Boys = 109 Done in Trissur, Kerala South India	Computerized spirometry	5 - 16	Male: PEFR = (1.2* Age in years) + (1.971* Height in cm) - 83.490	NA*

TABLE I (contd...)–*Description of Prediction Equations used in the Study*

Eqn. No.	Sour of data	Sample size	Equipment	Age	Equation	R value
8.	Raju, *et al*, 2003(10)	Boys = 1555 Done in Hyedrabad, South India	Wright's peak flow meter	5 - 15	Male: PEFR = (4.963* Height in cm) – 370.050	R^2 = 0.80 (r=0.89)
9.	Chowgule, Shetye and Parmar, 1995(11)	Total = 632 (Boys=354 Girls = 278) Done in Mumbai, Western India	Computerized spirometer	6 - 15	Male: PEFR = (0.0823* Height in cm) – 6.9387 Female: PEFR = (0.0704* Height in cm) – 5.5233	Boys: R^2 = 0.58 (R=0.76) Girls: R^2 = 0.41 (R = 0.64)
10.	Chowgule, Shetye and Parmar, 1995	Total = 632 (Boys=354 Girls = 278) Done in Mumbai, Western India	Computerized spirometer	6 - 15	Male: PEFR = (0.0706* Height in cm) + (0.0706* weight in kg) - 5.8592 Female: PEFR = (0.0303* Height in cm) + (0.0308* Weight in kg) + (0.1219* Age in years) – 2.3075	Boys: R^2 = 0.58 (R=0.76) Girls: R^2 = 0.45 (R = 0.67)
11.	Chowgule, Shetye and Parmar, 1995	Total = 632 (Boys=354 Girls = 278) done in Mumbai Western India	Computerized spirometer	6 - 15	Female: PEFR = (0.0539* Height in cm) + (0.1084* Age in years) - 4.4358	R^2 = 0.44 (R = 0.66)
12.	Aundhakar, *et al*,, 1985(12)	Total = 515 (Boys=261 Girls = 254) Done in Solapur, Maharashtra, Western India	Wright's peak flow meter	6 - 15	Male: PEFR = (4.16* Height in cm) – Female: PEFR = (4.802* Height in cm) – 371.075	NA*
13.	Verma, *et al.*, 2000 (13)	Total = 173 Region not specified	Wright's peak flow meter	8 - 13	Both boys and girls: PEFR = (14.506* Age in years) + (2.521* Height in cm) - 192.2274	R^2 = 0.667 (R = 0.817) SEE = 34.8
14.	Pande *et al.*, 1997(14)	Total = 1257 (Boys = 709 Girls = 548) Done in urban Delhi (n=745) and Nellore	Mini Wright's peak flow meter	6 - 17 (Delhi) 6 - 15 (Nellore)	Male: PEFR = (11.972* Age in years) + (2.969* Height in cm) - 274.628 Female: PEFR = (7.843* Age in years)+ (2.905* Height in cm) – 243.833	Boys: R^2 = 0.645 (R=0803) SEE = 46.39

TABLE I (contd...)–*Description of Prediction Equations used in the Study*

Eqn. No.	Sour of data	Sample size	Equipment	Age	Equation	R value
		Andhra Pradesh (n=512), North and South India				Girls: R2 = 0.742 (R^2 = 0.861) SEE = 45.39
15.	Malik, *et al.*, 1981 & 1982 (15-16)	Boys = 473 Girls = 132 Done in Ludhiana, Punjab, North India	Wright's peak flow meter	5 - 16	Male: PEFR = (4.92* Height in cm) – 368.89 Female: PEFR =(4.9* height in cm) - 371.8	Boys: R2 + NA* (R + NA*) SEE = 42.1 Girls: R^2 = NA* (R = NA) SEE = 43.8
16.	Singh & Peri (1978) (17)	Total = 663 (Boys = 321 Girls = 342) Done in Chennai, South India	Wright's peak flow meter	4 - 16	Male: PEFR = (24.46* Age in years) - 25.5) Female: PEFR = (24.47* Age in years) - 33.3	Boys: R^2 = 0.773 (R = 0.8794) SEE = 48.1 Girls: R^2 = 0.805 (R = 0.8971) SEE = 45.3
17.	Singh & Peri (1978) (17)	Total = 663 (Boys = 321 Girls = 342) Done in Chennai, South India	Wright's peak flow meter	4 - 16	Male: PEFR = (5.00* Height in cm) - 420.4 Female: PEFR = (5.03 *Height in cm) - 434.4	Boys: R^2 = 0.824 (R = 0.9076) SEE = 42.4 Girls: R^2 = 0.809 (R = 0.8998) SEE = 44.7
18.	Singh & Peri (1978) (17)	Total = 663 (Boys = 321 Girls = 342) Done in Chennai, South India	Wright's peak flow meter	4 - 16	Male: PEFR = (10.75* Weight in kg) - 46.0 Female: PFER = (8.611 *Weight in kg) - 7.8	Boys: R^2 = 0.786 (R = 0.8864) SEE = 46.8 Girls: R^2 = 0.764 (R= 0.8740) SEE = 49.8

*Not available. Validation for all equations are not available

TABLE II–*Characteristics of the Study Group*

Characteristics	Total (n = 141)	Male (n = 81)	Female (n = 60)
Age (yr)	11.3 (8-13)	11.4 (8-13)	11.2 (8-13)
Height (cm)	138.5 (109.5-176.5)	138.1 (109.5-176.5)	138.9 (112.4-172.7)
Weight (kg)	29.5 (15.6-55.2)	29.3 (16.3-51.5)	29.9 (15.6-55.2)
PFER (1/min)	298 (160-530)	301 (160-530)	293 (160-430)

Mean (Range)

(equation 13) to –98.7 L/min (equation 7) in boys and 14.35 L/min (equation 4) to –97.9 L/min (equation 1) in girls (*Tables V* & *VI*).

In summary, equation 4 appeared to be best suited for our study group on several counts:

(*a*) A relatively good correlation between measured PEFR and predicted value.

(*b*) Greatest number within normal limits (10% of predicted) with 55.6 % in boys and 53.3% in girls.

(*c*) An almost even extent of over- and under-estimation (24.1% and 21.3% respectively).

(*d*) A low bias compared to all other equations.

Discussion

Seventeen prediction equations for boys and 16 equations for girls were evaluated for their suitability as reference values for a study population between of 8 to 13 years of age. The results of this study highlight the problems that are associated with using prediction equations for normative data.

Equation 4 among the eight that were tested was found most suitable for our study population. Beyond the specific findings of this study, however, is the demonstration of a practical approach to choosing a regression equation when multiple such equations are available.

Our suggested approach would be to:

(*a*) Evaluate the strengths and weaknesses of the regression equation itself and

(*b*) Test the regression equation on a small sample of the intended study population using multiple methods to ascertain suitability.

This is, indeed, the approach that has been suggested by the ATS(1).

For the purpose of identifying the most suitable regression equation the ATS has suggested evaluating the following questions(1):

(*a*) Have the investigators used acceptable methods and equipment?

(*b*) Has the study sample been adequately described?

(*c*) Is the statistical approach to equation generation adequately described?

(*d*) Was the equation validated on an independent study sample?

In the present study, the papers reviewed

TABLE III–*Percentage distribution of comparable estimates over-estimates (> + 10%), and under-estimates (< –10%) for each prediction equation studied (Equations 1 to 9)*

	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 6	Equation 7	Equation 8	Equation 9
Indian Children* (n = 141)									
Comparable	9.2	38.3	41.1	54.6	39.0	5.0	–	–	29.8
Over-estimation	1.4	14.9	12.8	24.1	8.5	1.4	–	–	9.9
Under-estimation	89.4	46.8	46.1	21.3	52.5	93.6	–	–	60.3
Correlation^{+}	0.731	0.755	0.750	0.740	0.710	0.762	–	–	0.761
Indian boys (n=81):									
Comparable	8.6	48.1	50.6	55.6	44.4	6.2	1.2	51.9	33.3
Over-estimation	1.2	12.3	12.3	17.3	9.9	0	1.2	12.3	7.4
Under-estimation	90.1	39.5	37.0	27.2	45.7	93.8	97.5	35.8	59.3
Correlation^{+}	0.787	0.789	0.797	0.789	0.724	0.792	0.792	0.789	0.790
Indian girls (n=60):									
Comparable	10.0	25.0	28.3	53.3	31.7	3.3	–	–	25.0
Over-estimation	1.7	18.3	13.3	33.3	6.7	3.3	–	–	13.3
Under-estimation	88.3	56.7	58.3	13.3	61.7	93.3	–	–	61.7
Correlation^{+}	0.665	0.719	0.709	0.719	0.740	0.722	–	–	0.719

*Includes both boys and girls; $^{+}$All correlations (predicted versus measured) PEFR values are significant with P<0.001;

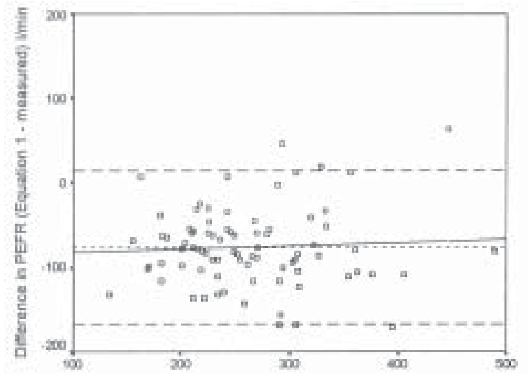
A paired t-test indicates that means of predicted values obtained from each of these equations are significantly different (P=0.0005) from the actual PEFR values.

TABLE IV–*Percentage Distribution of Comparable Estimates Over-Estimates (> + 10%), and Under-Estimates (<–10%) For Each Prediction Equation Studied (Equations 1 to 9)*

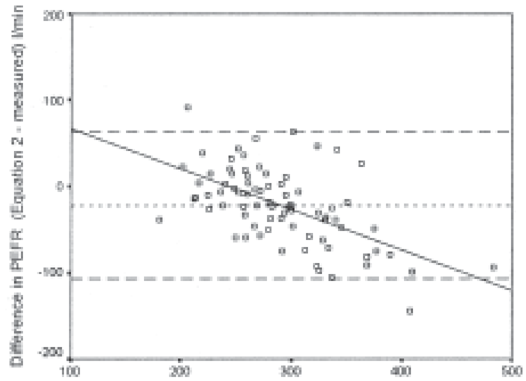
	Equation 10	Equation 11	Equation12	Equation 13	Equation 14	Equation 15	Equation 16	Equation 17	Equation 18
Indian children* (n = 141):									
Normal	27.7	–	49.6	46.1	35.5	53.9	29.1	31.9	29.1
Over-estimation	46.1	–	26.2	44.7	7.8	32.6	6.4	13.5	9.9
Under-estimation	26.2	–	24.1	9.2	56.7	13.5	64.5	54.6	61.0
Correlation^{+}	0.628	–	0.744	0.755	0.754	0.753	0.642	0.753	0.698
Indian boys (n = 81):									
Normal	24.7	–	51.9	43.2	40.7	54.3	32.1	37.0	34.6
Over-estimation	75.3	–	25.9	44.4	11.1	30.9	7.4	11.1	9.9
Under-estimation	0	–	22.2	12.3	48.1	14.8	60.5	51.9	55.6
Correlation^{+}	0.796	–	0.789	0.768	0.779	0.789	0.642	0.789	0.761
Indian girls (n = 60):									
Normal	25.0	28.3	46.7	50.0	28.3	53.3	25.0	25.0	21.7
Over-estimation	13.3	10.0	26.7	45.0	3.3	35.0	5.0	16.7	10.0
Under-estimation	61.7	61.7	26.7	5.0	68.3	11.7	70.0	58.3	68.3
Correlation^{+}	0.732	0.743	0.719	0.755	0.747	0.719	0.705	0.719	0.616

*Includes both boys and girls; $^{+}$All correlations (predicted versus measured) PEFR values are significant with $P<0.001$;

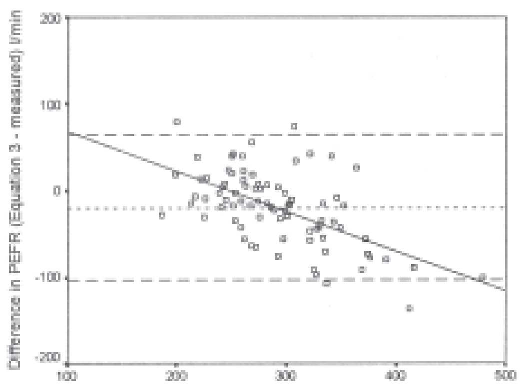
A paired t-test indicates that means of predicted values obtained from each of these equations are significantly different ($P=0.0005$) from the actual PEFR values.



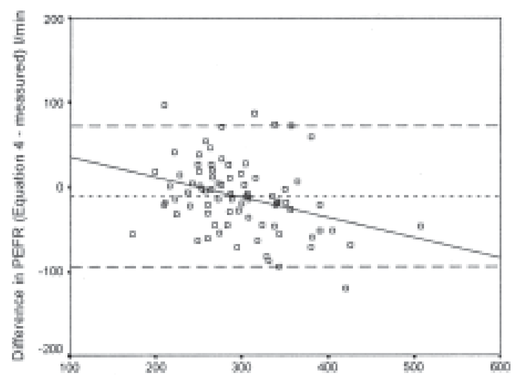
Average PEFR (Equation 1 and PEFR) L/min
r = +0.06 p = 0.611
(*a*)



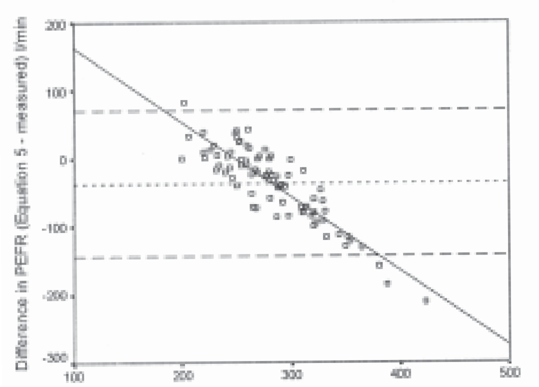
Average PEFR (Equation 2 and PEFR) L/min
r = –0.77 p = < 0.001
(*b*)



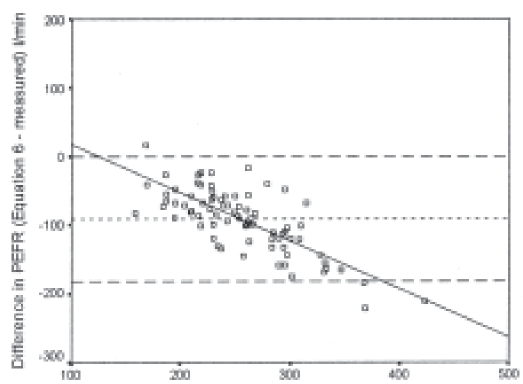
Average PEFR (Equation 3 and PEFR) L/min
r = –0.77 p = <0.001
(*c*)



Average PEFR (Equation 4 and PEFR) L/min
r = – 0.59 p = < 0.001
(*d*)

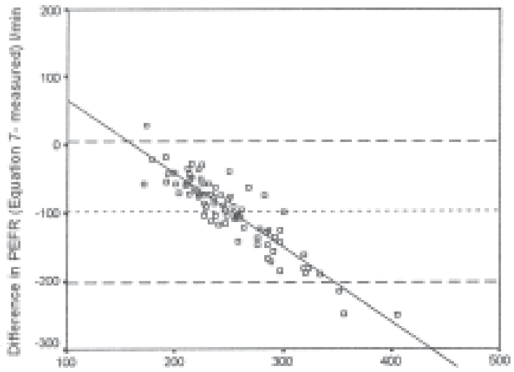


Average PEFR (Equation 5 and PEFR) L/min
r = –0.95 p = <0.001
(*e*)

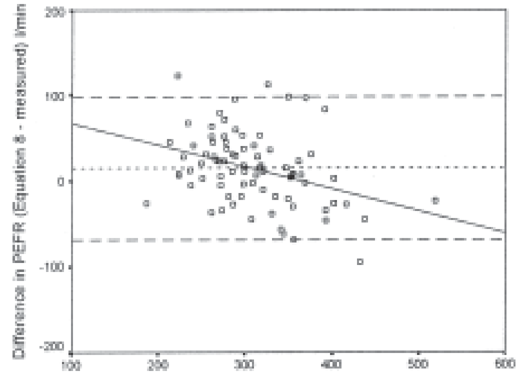


Average PEFR (Equation 6 and PEFR) L/min
r = –0.88 p = <0.001
(*f*)

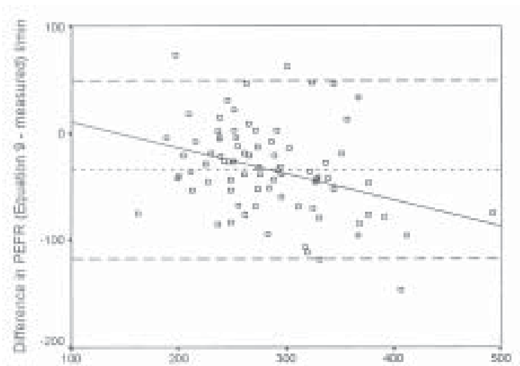
Fig. 1. Bland-Altman plots for difference against mean PEFR in boys.



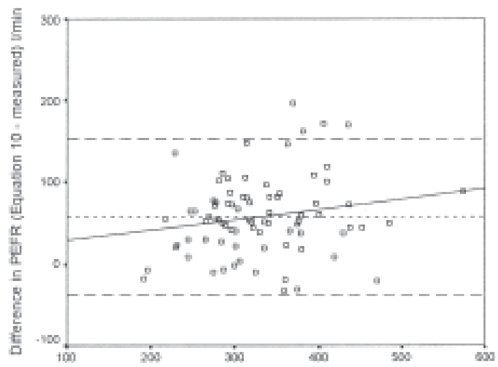
Average PEFR (Equation 7 and PEFR) L/min
r = –0.96 p = <0.001
(*g*)



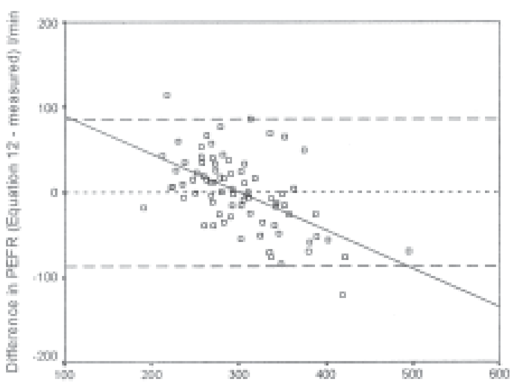
Average PEFR (Equation 8 and PEFR) L/min
r = –0.61 p = <0.001
(*h*)



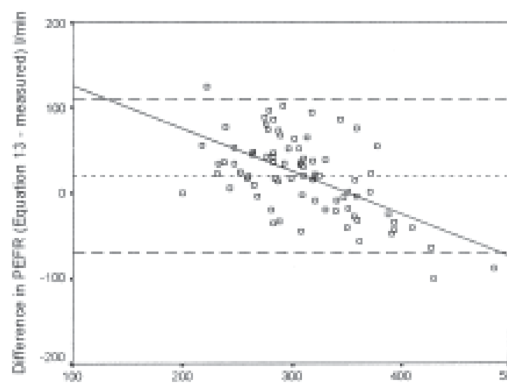
Average PEFR (Equation 9 and PEFR) L/min
r = –0.34 p = 0.002
(*i*)



Average PEFR (Equation 10 and PEFR) L/min
r = +0.18 p = 0.102
(*j*)

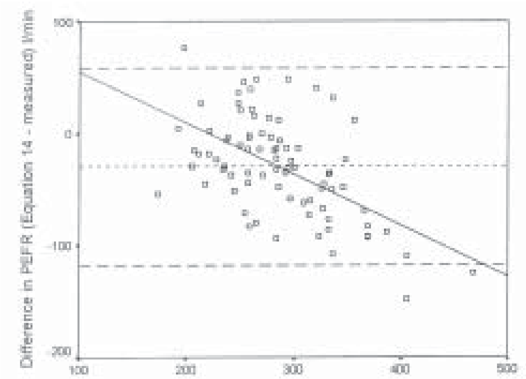


Average PEFR (Equation 12 and PEFR) L/min
r = –0.57 p = <0.001
(*k*)

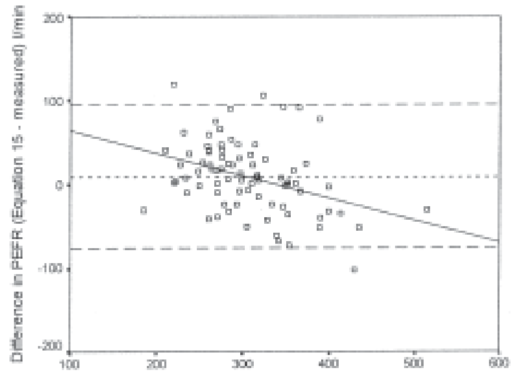


Average PEFR (Equation 13 and PEFR) L/min
r = – 0.59 p = <0.001
(*l*)

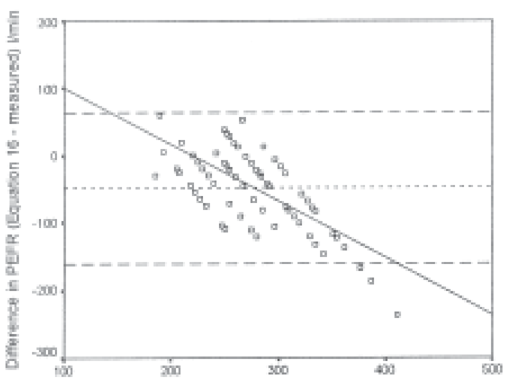
Fig. 1. Bland-Altman plots for difference against mean PEFR in boys.



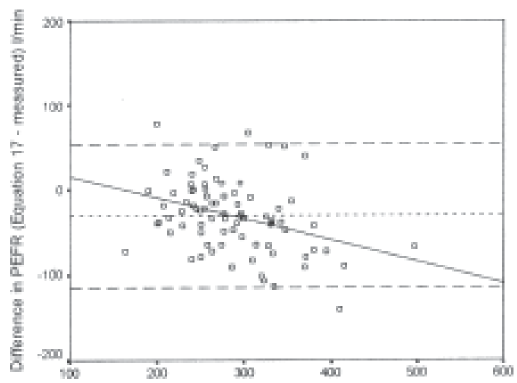
Average PEFR (Equation 14 and PEFR) L/min
r = –0.56 p = <0.001
(*m*)



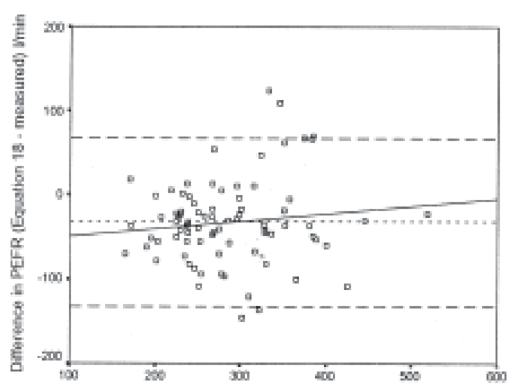
Average PEFR (Equation 15 and PEFR) L/min
r = –0.37 p = <0.001
(*n*)



Average PEFR (Equation 16 and PEFR) L/min
r = –0.70 p = <0.001
(*o*)

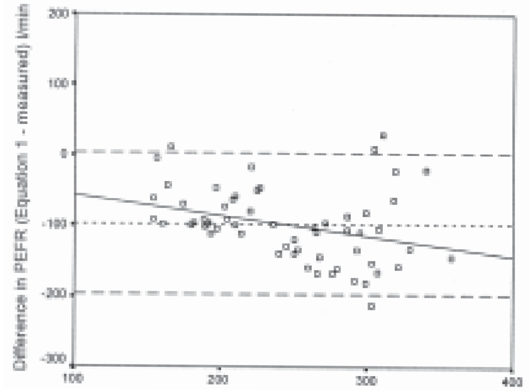


Average PEFR (Equation 17 and PEFR)L/min
r = –0.35 p = <0.002
(*p*)

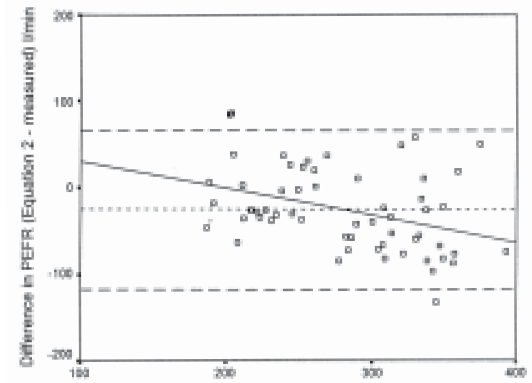


Average PEFR (Equation 18 and PEFR) L/min
r = +0.12 p = 0.279
(*q*)

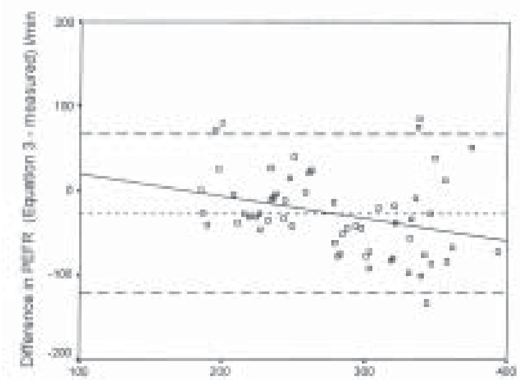
Fig. 1. Bland-Altman plots for difference against mean PEFR in boys.



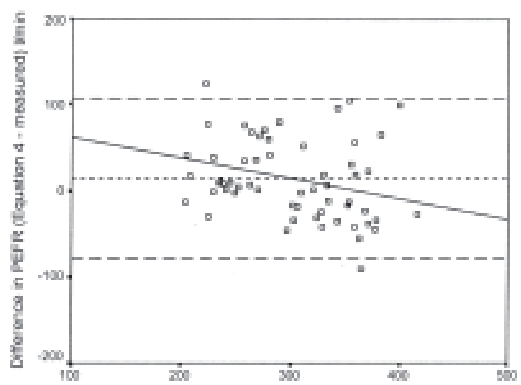
Average PEFR (Equation 1 and PEFR) L/min
r = –0.63   p = <0.001
(*a*)



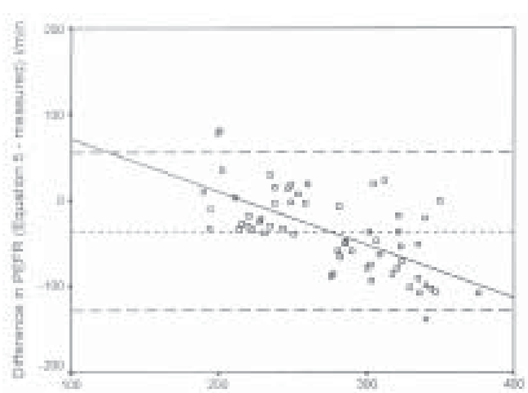
Average PEFR (Equation 2 and measured) L/min
r = –0.65   p = <0.001
(*b*)



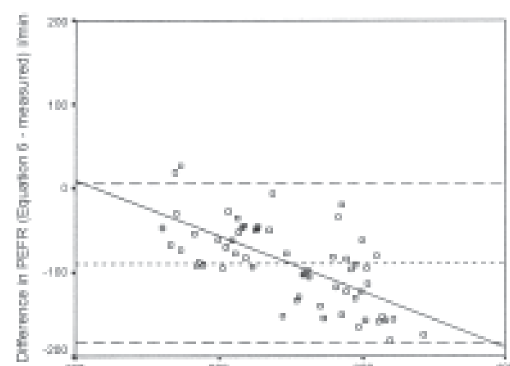
Average PEFR (Equation 3 and measured) L/min
r = –0.61   p = <0.001
(*c*)



Average PEFR (Equation 4 and measured) L/min
r = –0.59   p = <0.001
(*d*)

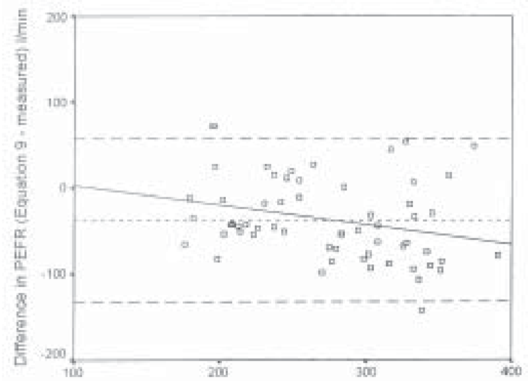


Average PEFR (Equation 5 and measured) L/min
r = –0.83   p = <0.001
(*e*)

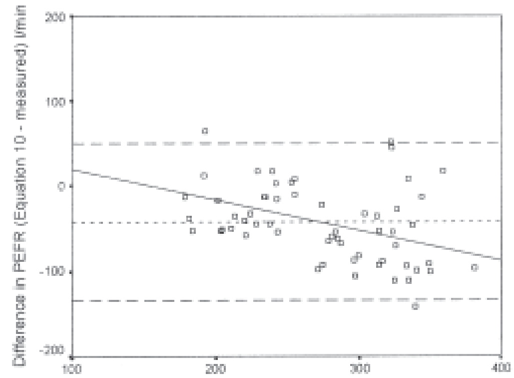


Average PEFR (Equation 6 and PEFR) L/min
r = –0.70   p = <0.001
(*f*)

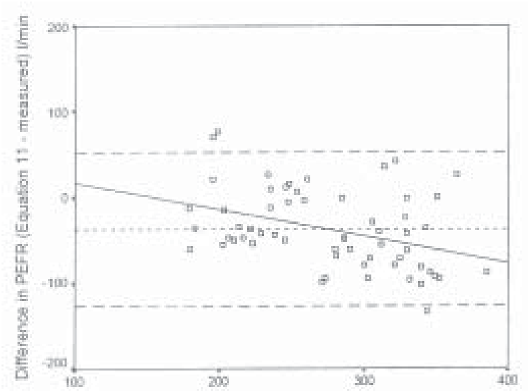
Fig. 2. Bland-Altman plots for difference againstmean PEFR in girls.



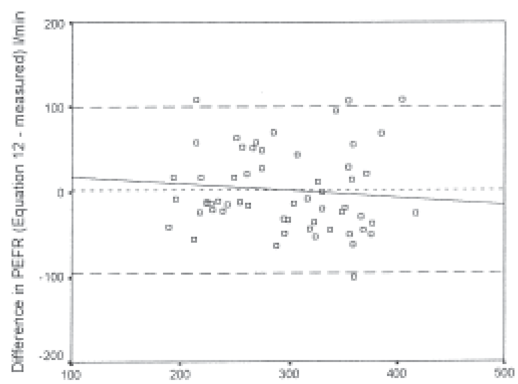
Average PEFR (Equation 9 and PEFR) L/min
r = –0.28 p = 0.033
(*g*)



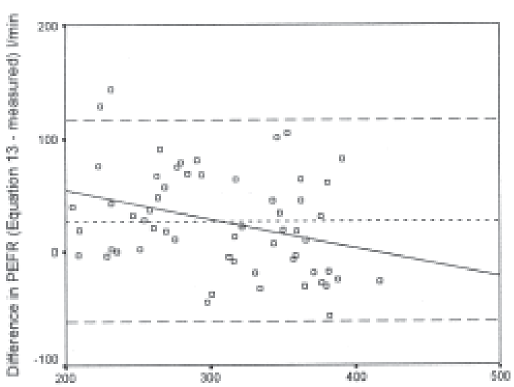
Average PEFR (Equation 10 and PEFR) L/min
r = –0.42 p = <0.001
(*h*)



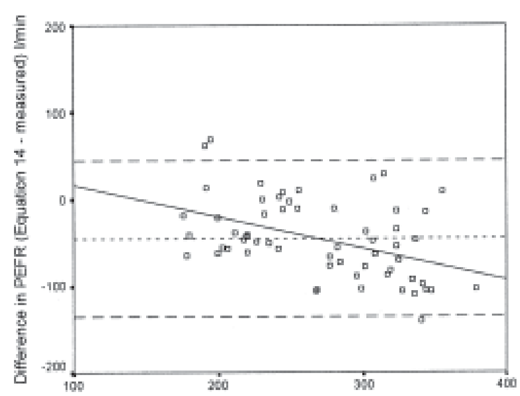
Average PEFR (Equation 11 and PEFR) L/min
r = –0.39 p = 0.002
(*i*)



Average PEFR (Equation 12 and PEFR) L/min
r = –0.10 p = 0.447
(*j*)

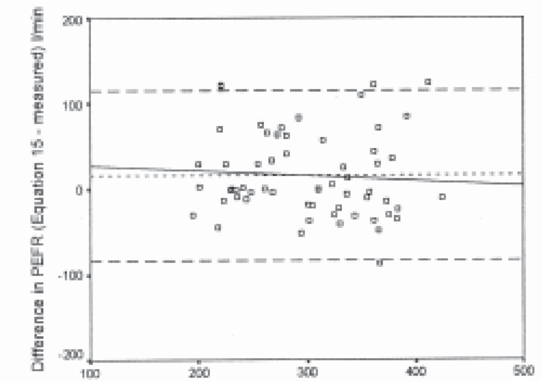


Average PEFR (Equation 13 and PEFR) L/min
r = –0.33 p = 0.011
(*k*)

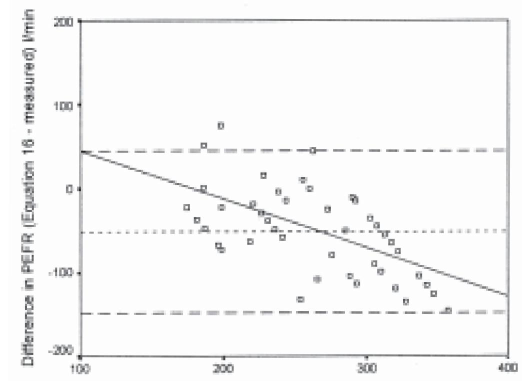


Average PEFR (Equation 14 and PEFR) L/min
r = –0.44 p = <0.001
(*l*)

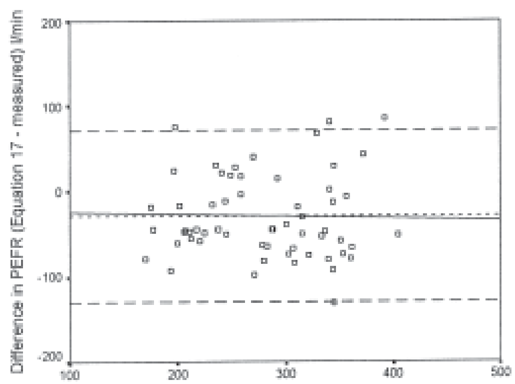
Fig. 2. Bland-Altman plots for difference against mean PEFR in girls.



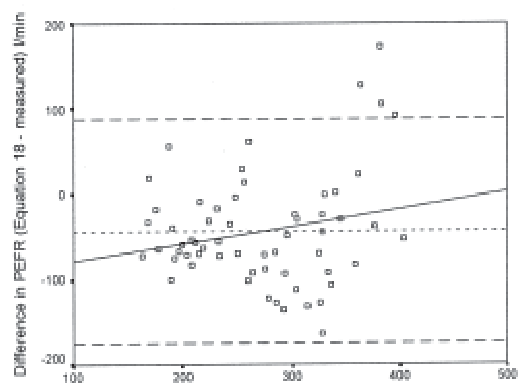
Average PEFR (Equation 15 and PEFR) L/min
r = –0.07 p = 0.590
(*m*)



Average PEFR (Equation 16 and PEFR) L/min
r = –0.60 p = <0.001
(*n*)



Average PEFR (Equation 17 and PEFR) L/min
r = –0.03 p = 0.799
(*o*)



Average PEFR (Equation 18 and PEFR) L/min
r = +0.20 p = 0.119
(*p*)

Fig. 2. Bland-Altman plots for difference against mean PEFR in girls.

allowed an assessment of the first two questions. With regard to the third question, only 10 equations provided correlation coefficients for the equations that were generated and 6 provided in addition, the standard error of the estimate. Further statistical analyses on the statistical validity of the generated regression equations were not available. In addition, more detail regarding the process of generation of the regression equations in statistical terms would have allowed better evaluation. None of the equations had accompanying validation data on an independent data set.

Thus, there are clear problems, some of which are based on the insufficiency of data, which make a choice of regression equations for PEFR difficult. In the absence of totally acceptable information on 'regression equations of PEFR based on ATS recommendations, we have described a practical approach that allows clinicians and researchers to evaluate whSich equation to use for local data sets.

This paper provides a practical step by step approach to choosing prediction equations when multiple equations are available. The method includes critical evaluation of the

TABLE V–*Bias Observed in Values Obtained Through the 18 Equations in Boys*

Equation	Mean difference (bias) ± SD (SE) (L/min)	Limits of agreement (L/min) Upper limit	Limits of agreement (L/min) Lower limit	Confidence interval for the bias (L/min)	Confidence interval of upper limit (L/min)	Confidence interval of lower limit (L/min)
Boys (n = 81)						
1	–76.2 ± 46.0 (5.1)	+13.99	–166.42	–86.4 to –66.0	–3.7 to 31.7	–184.1 to –148.7
2	–22.0 ± 43.6 (4.8)	+63.46	–107.38	–31.6 to –12.3	+46.7 to +80.2	–124.2 to –90.6
3	–19.2 ± 43.0 (4.8)	+64.96	–103.40	–28.7 to –9.7	+48.4 to +81.5	–119.9 to –86.9
4	–11.0 ± 42.6 (4.7)	+72.45	–94.38	–20.4 to –1.6	+56.1 to 88.8	–110.8 to –78.0
5	–36.7 ± 54.6 (6.1)	+70.23	–143.68	–48.8 to –24.7	+49.2 to 91.2	–164.7 to –122.7
6	–91.7 ± 46.4 (5.2)	–0.79	–182.59	–102.0 to 81.4	–18.6 to +17.1	–200.4 to –164.7
7	–98.7 ± 52.9 (5.9)	+4.99	–202.32	–110.4 to –87.0	–15.4 to –25.4	–222.7 to –182.0
8	+14.5 ± 42.5 (4.7)	+97.85	–68.87	5.1 to 23.9	+81.5 to + 114.2	–82.5 to –52.5
9	–34.0 ± 42.4 (4.7)	+49.20	–117.17	–43.4 to –24.6	+32.9 to +65.5	–133.5 to –100.8
10	57.9 ± 46.5 (5.3)	+150.99	–35.19	47.4 to 68.5	+132.7 to + 169.3	–53.5 to –16.9
12	–0.5 ± 43.4 (4.8)	+84.50	–85.59	–10.2 to + 9.10	+67.8 to 101.2	–102.3 to –68.9
13	+19.8 ± 45.3 (5.0)	+108.53	–68.93	+9.7 to +29.9	+91.11 to +125.9	–86.4 to –51.5
14	–29.5 ± 44.1 (4.9)	+56.99	–115.99	–39.3 to –19.7	+40.00 to 74.0	–133.0 to –99.0
15	+9.7 ± 42.5 (4.7)	+93.06	–73.59	+0.3 to +19.2	+76.7 to +109.4	–90.0 to –57,2
16	–48.6 ± 56.2 (6.2)	+61.50	–158.73	–61.1 to –36.1	+39.9 to +83.1	–180.4 to –137.1
17	–30.7 ± 42.5 (4.7)	+52.61	–114.08	–40.2 to –21.3	+36.2 to 69.0	–130.4 to –97.7
18	–32.1 ± 50.2 (5.6)	+66.17	–130.41	–43.3 to –20.9	+46.9 to 85.5	–149.7 to 111.1

TABLE VI–*Bias Observed in Values Obtained Through the 18 Equations in Girls*

Equation	Mean difference (bias) ± SD (SE) (L/min)	Limits of agreement (L/min)		Confidence interval for the bias (L/min)	Confidence interval of upper limit (L/min)	Confidence interval of lower limit (L/min)
		Upper limit	Lower limit			
Girls (n = 60)						
1	–97.9 ± 51.1 (6.6)	+2.23	–198.07	–111.1 to –84.7	–20.6 to 25.1	–220.9 to –175.2
2	–25.8 ± 47.1 (6.1)	+66.48	–118.08	–38.0 to –13.6	45.4 to 87.5	–139.1 to –97.0
3	–27.6 ± 48.1 (6.2)	+66.68	–121.81	–40.0 to –15.1	45.2 to 88.2	–143.3 to –100.3
4	+14.4 ± 47.5 (6.1)	+107.35	–78.65	2.1 to 26.6	86.1 to 128.6	–99.9 to –57.45
5	–36.5 ± 46.9 (6.1)	+55.38	–128.26	–48.6 to –24.3	34.4 to 76.3	–149.2 to –107.3
6	–89.6 ± 48.2 (6.2)	+4.89	–183.98	–101.99 to –77.1	–16.7 to 26.4	–205.5 to –162.4
9	–37.9 ± 47.5 (6.1)	+55.22	–131.06	–50.2 to –25.7	+34.0 to +76.5	–152.3 to –109.8
10	–41.8 ± 46.1 (6.0)	+48.53	–132.13	–53.7 to –29.9	+27.9 to +69.1	–152.7 to –111.5
11	–37.2 ± 45.3 (5.8)	+51.56	–125.90	–48.9 to –25.5	+31.3 to +71.8	–146.1 to –105.7
12	+2.7 ± 49.2 (6.4)	+99.11	–93.70	–10.0 to +15.4	+77.1 to 121.1	–115.7 to –71.7
13	+27.6 ± 44.5 (5.7)	+114.71	–59.56	+16.1 to +39.1	+94.8 to +134.6	–79.4 to –39.7
14	–45.5 ± 44.9 (5.8)	+42.59	–133.64	–57.1 to –33.9	+22.5 to +62.7	–153.7 to –113.5
15	+15.6 ± 49.6 (6.4)	+112.80	–81.59	+2.8 to +28.4	+90.6 to +135.0	–103.8 to –59.4
16	–15.8 ± 48.5 (6.3)	+43.22	–146.80	–64.4 to –39.3	+21.5 to + 64.8	–168.5 to –125.1
17	–28.9 ± 50.2 (6.5)	+69.36	–127.22	–41.9 to –16.0	+46.9 to +91.8	–149.7 to –104.8
18	–43.8 ± 65.4 (8.4)	+84.34	–171.91	–60.7 to –26.9	+55.1 to +113.6	–201.2 to –142.7

Key Messages

- Clinical use of peak expiratory flow rates require comparisons with normative/standard data
- Where multiple regression equations are available, evaluation using a small study sample and multiple statistical methods will allow investigators to make a choice.

prediction equations themselves as well as an analysis of suitability on a small independent data set.

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Contributors: SS conducted the analyses and wrote the first draft of the paper. BD was involved in the study design and conceptualization and in data collection. MV conceptualized the study and edited the manuscript.

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