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Predictive Regression Equations of Flowmetric and Spirometric Peak Expiratory Flow in Healthy Moroccan Children

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ABSTRACT

Introduction: Peak Expiratory Flow (PEF) has never been characterised among healthy Moroccan school children.

Aim: To study the relationship between PEF and anthropometric parameters (sex, age, height and weight) in healthy Moroccan school children, to establish predictive equations of PEF; and to compare flowmetric and spirometric PEF with Forced Expiratory Volume in 1 second (FEV1).

Materials and Methods: This cross-sectional study was conducted between April, 2016 and May, 2016. It involved 222 (122 boys and 100 girls) healthy school children living in Ksar el-Kebir, Morocco. We used mobile equipments for realisation of spirometry and peak expiratory flow measurements. SPSS (Version 22.0) was used to calculate Student's t–test, Pearson's correlation coefficient and linear regression.

Results: Significant linear correlation was seen between PEF, age and height in boys and girls. The equation for prediction of flowmetric PEF in boys was calculated as 'F-PEF = -187+ 24.4 Age + 1.61 Height' (p-value<0.001, r=0.86), and for girls as 'F-PEF = -151 + 17Age + 1.59Height' (p-value<0.001, r=0.86). The equation for prediction of spirometric PEF in boys was calculated as 'S-PEF = -199+ 9.8Age + 2.67Height' (p-value<0.05, r=0.77), and for girls as 'S-PEF = -181 + 8.5Age + 2.5Height' (p-value<0.001, r=0.83). The boys had higher values than the girls. The performance of the Mini Wright Peak Flow Meter was lower than that of a spirometer.

Conclusion: Our study established PEF predictive equations in Moroccan children. Our results appeared to be reliable, as evident by the high correlation coefficient in this sample. PEF can be an alternative of FEV1 in centers without spirometry.

Keywords: Forced expiratory volume in 1 second, Peak flow meter, Spirometer

INTRODUCTION

Asthma is the most common chronic inflammatory disease in pediatric population. It is among the leading causes of school absenteeism, hospitalisation and frequent visits to hospital emergency rooms [1]. Objective measures of lung functions are needed to make the initial diagnosis and to avoid prescribing wrong medication. Bronchial obstruction and its reversibility are major elements defining asthma. It is essential to evaluate them in an objective manner before making the diagnosis of asthma in a definitive way. The two most commonly used ways to measure the expiratory flow and appreciate the existence and the importance of an obstructive syndrome and its reversibility or variability are peak flowmeter and spirometry [2]. PEF is the maximum flow generated during forced expiration after a forced inspiration to the total lung capacity and can be measured using spirometry. Moreover, a peak flow meter is more available and less expensive than spirometry. It is also light and compact. It can be easily used as a tool for screening bronchial obstruction [3]. Spirometer is known to be accurate, but expensive, less available out of respiratory labs, and interpretation of its results needs previous learning. Even if the spirometry represents the "Gold standard" for most asthmatic patients, it is easier to measure PEF than FEV1 during asthma attacks.

Mechanical peak flow meters are mostly used in emergency departments, being inexpensive and easy to use. Some studies showed that, properly used peak flow meters help to improve the quality of life of asthmatic patients by allowing them to assess their asthma, adapt their treatments and anticipate attacks, as long as PEF detects obstruction before these patients feel oppressed [4]. In addition, results obtained from PEF measurements are only interpretable by the expected values, i.e., "reference values" of the population to which the individual belong. In the absence of Moroccan predictive equations, the majority of Moroccan physicians are using international equations adapted by Clement Clarke from the book of Cotes JE et al., and that have not been validated in our population [5]. This may cause false positives and false negatives, explaining the overestimation of normal subjects, and the underestimation of asthmatic subjects. The use of these inadequate reference values and equations in the Moroccan population can lead to errors of interpretation, which is the reason that motivated our study.

This study is part of the Global Lung Initiative in Morocco project (GLIM), and its objectives are to study the relationship between PEF and anthropometric parameters (sex, age, height and weight) in healthy Moroccan school children; to establish predictive equations of PEF; and to compare flowmetric and spirometric PEF, with FEV1.

MATERIALS AND METHODS

This cross-sectional study was conducted from April, 2016 to May, 2016. We worked during eight separated days for measurement of lung functions at the Maarif School, located in the town of Ksar el-Kebir, in Northern Morocco. It concerned 222 school children selected from 303 participants out of total 678 school pupils. The selection was based on inclusion and exclusion criteria. Children included were Moroccan, who passed a full clinical assessment and correctly performed the spirometric and flowmetric maneuvers. Exclusion criteria involved any cardiorespiratory, neurological, or musculoskeletal diseases; smoking history (active, passive or former); high level sport practice; obesity; and abnormal spirometric curve. We noted height and weight for every participant. For this study, we made measurements using two Spirolab III spirometers (Medical International Research, Roma, Italy) and Mini-Wright peak flow meters (Clement Clarke International Ltd., London, UK).

This study received the approval of the Ethical Committee of the Faculty of Medicine and Pharmacy of Rabat, Morocco. The consent of parents was obtained before the start of the study. Each child had to present his health records and validate a full clinical assessment performed by the pulmonologist of the study. F-PEF (Flowmetric Peak Expiratory Flow) was measured three times for each child, and the best performance was retained and noted. Three to five spirometric maneuvers were conducted to get the best values of S-PEF (Spirometric Peak Expiratory Flow) and FEV1, according to the criteria of acceptability and reproducibility of the American Thoracic Society/European Respiratory Society (ATS/ERS) recommendations.

STATISTICAL ANALYSIS

All results were transferred and processed by the Statistical Package for the Social Sciences software (Version 22.0, SPSS Statistics/ IBM Corp, Chicago IL, USA). Correlations between anthropometric parameters and F-PEF, S-PEF, and FEV1 were studied using the Pearson correlation coefficient. Correlations have been studied in simple and multiple linear regression to retain influential parameters in a statistically significant way. Thus, we established predictive equations of F-PEF, S-PEF, and FEV1 for both sexes based on age and height. Correlations between F-PEF, S-PEF, and FEV1 were studied using Pearson's correlation coefficient and Simple linear regression to establish predictive equations.

RESULTS

Descriptive study: From the 303 children who presented to our stand, 81 were excluded (35 children did not validate the full clinical assessment, 9 were of foreign nationalities and 37 were incorrect spirometry maneuvers). Only 222 children were selected, 122 (55%) boys and 100 (45%) girls, aged between three and 13 years old.

[Table/Fig-1] summarizes anthropometric and ventilator characteristics. S-PEF is always greater than F-PEF (p-value<0.001). The same was observed in boys and girls (p-value<0.001).

Analytical Study: [Table/Fig-2] shows correlations of F-PEF with age, height and weight in simple and multiple linear regressions in both sexes. Thus, predictive equation of F-PEF from age and height for boys in this analysis is F-PEF = -187+ 24.4Age + 1.61Height (p-value<0.001, r=0.86), and for girls; F-PEF = -151 + 17Age + 1.59Height (p-value<0.001, r=0.86).

[Table/Fig-3] shows correlations of S-PEF with anthropometric parameters for boys and girls. Thus, predictive equations of S-PEF for boys is S-PEF = -199 + 9.8Age (years) + 2.67Height (cm) (r=0.77; p-value<0.05), and for girls it is; S-PEF = -181 + 8.5Age (years) + 2.5 Height (cm) (r=0.83; p-value<0.001).

[Table/Fig-4] shows correlation of FEV1 with age, height and weight in simple and multiple linear regressions in both sexes. Thus, predictive equation of FEV1 for boys; FEV1= -1.93 + 0.03Age (years)

Parameters	Sample (n=222)		Boys (n=122)		Girls (n=100)		p-value
	Mean± SD	Range	Mean± SD	Range	Mean± SD	Range	
Age (years)	7.13± 1.95	3.68-13.02	7.22±1.9	4.22-13.02	7.03± 2.01	3.68-12.66	0.493
Height (cm)	122.22± 13.75	99-172	123.84± 12.96	100-161	120.69± 13.98	99-172	0.125
Weight (Kg)	26.12± 8.15	15-64	26.75± 8.43	16-64	25.35± 7.77	15-63	0.2
F-PEF (L/min)	176±72	70-500	189±76	85-500	161±64	70-370	0.04
S-PEF (L/min)	194±65	58-518	201±67	58-496	185±62	88-518	0.06
FEV1 (L/s)	1.34± 0.44	0.64-3.26	1.37± 0.44	0.64-3.26	1.28± 0.42	0.72-3.2	0.113

[Table/Fig-1]: The anthropometric and ventilatory characteristics of the sample.

	Parameters	Correlation with	Correlation coefficient (r)	p-value
Boys	Pearson Correlation			
	Age	F-PEF	0.854	<0.001
	Height		0.818	<0.001
	Weight		0.727	<0.001
	Multiple linear regression (3 parameters)			
	Age	F-PEF	0.512	<0.001
	Height		0.256	0.021
	Weight		0.127	0.132
	Multiple linear regression (2 parameters)			
	Age	F-PEF	0.61	<0.001
	Height		0.27	0.009
Girls	Pearson Correlation			
	Age	F-PEF	0.846	<0.001
	Height		0.826	<0.001
	Weight		0.742	<0.001
	Multiple linear regression (3 parameters)			
	Age	F-PEF	0.541	<0.001
	Height		0.398	0.011
	Weight		-0.062	0.611
	Multiple linear regression (2 parameters)			
	Age	F-PEF	0.536	<0.001
	Height		0.346	0.004

[Table/Fig-2]: The correlation of F-PEF with age, height and weight in simple and multiple linear regression study among both sexes.

	Parameters	Correlation with	Correlation Coefficient (r)	p-value
Boys	Pearson Correlation			
	Age	S-PEF	0.734	<0.001
	Height		0.760	<0.001
	Weight		0.691	<0.001
	Multiple linear Regression (3 parameters)			
	Age	S-PEF	0.285	0.029
	Height		0.362	0.028
	Weight		0.169	0.131
	Multiple linear Regression (2 parameters)			
	Age	S-PEF	0.276	0.035
	Height		0.513	<0.001
Girls	Pearson Correlation			
	Age	S-PEF	0.793	<0.001
	Height		0.831	<0.001
	Weight		0.824	<0.001
	Multiple linear Regression (3 parameters)			
	Age	S-PEF	0.243	0.044
	Height		0.452	<0.001
	Weight		0.199	0.208
	Multiple linear Regression (2 parameters)			
	Age	S-PEF	0.336	<0.001
	Height		0.555	<0.001

[Table/Fig-3]: The correlation of S-PEF with age, height and weight in simple and multiple linear regression study among both sexes.

+ 0.025Height (cm) (r=0.84; p-value<0.001), and for girls; FEV1= -1.48 + 0.052Age (years) + 0.02Height (cm) (r=0.88; p-value< 0.001).

Among boys, we found a strong positive correlation between F-PEF and S-PEF (r=0.87; p-value<0.001). We can then deduce from this analysis, a predictive equation of F-PEF based on S-PEF: F-PEF=

	Parameters	Correlation with	Correlation Coefficient (r)	p-value
Boys	Pearson Correlation			
	Age	FEV1	0.811	<0.001
	Height		0.846	<0.001
	Weight		0.781	<0.001
	Multiple linear regression (3 parameters)			
	Age	FEV1	0.323	<0.001
	Height		0.435	<0.001
	Weight		0.144	0.164
	Multiple linear regression (2 parameters)			
	Age	FEV1	0.327	<0.001
	Height		0.568	<0.001
Girls	Pearson Correlation			
	Age	FEV1	0.874	0.001
	Height		0.877	<0.001
	Weight		0.834	0.001
	Multiple linear regression (3 parameters)			
	Age	FEV1	0.424	<0.001
	Height		0.303	0.033
	Weight		0.214	0.092
	Multiple linear regression (2 parameters)			
	Age	FEV1	0.527	<0.001
	Height		0.276	<0.001

[Table/Fig-4]: The correlation of FEV1 with age, height and weight in simple and multiple linear regression study among both sexes.

Sex	Variables	Regression Parameters				R	R^2	SEE	RSD
		Constant	Age	Height	Weight				
Boys	F-PEF	-187	24.4	1.61	-	0.86	0.74	38.9	38.6
	S-PEF	-199	9.8	2.67	-	0.77	0.59	43.4	43.0
	FEV1	-1.93	0.030	0.025	-	0.84	0.72	0.236	0.234
Girls	F-PEF	-151	17	1.59	-	0.86	0.74	33.2	32.8
	S-PEF	-181	8.5	2.5	-	0.83	0.69	34.4	34.0
	FEV1	-1.48	0.052	0.020	-	0.88	0.78	0.199	0.197

[Table/Fig-5]: Regression models for predicting F-PEF, S-PEF and FEV1 in Moroccan children.
R: Multiple Correlation coeffi cients; R^2: Determination coefficients; SEE: Standard error of estimate; RSD: Residual Standard Deviation.

-10 + 0.987 S-PEF.

Among girls, we found a strong positive correlation too between F-PEF and S-PEF (r=0.82; p-value<0.001). We can then deduce from this analysis, a predictive equation of F-PEF based on S-PEF: F-PEF = 3 + 0.856 S-PEF.

Among boys, we found a strong positive correlation between F-PEF and FEV1 (r=0.753; p-value<0.001). We can then deduce from this analysis, the predictive equation of F-PEF (L/min) based on FEV1 (L/s): F-PEF = 10 + 129.687 FEV1.

Among girls, we found a strong positive correlation between F-PEF and FEV1(r=0.75; p-value<0.001). We can deduce through this analysis, an equation for predicting F-PEF (L/min) based on FEV1 (L/s): F-PEF= 14 + 114.492 FEV1.

Among boys we found a strong positive correlation between S-PEF and FEV1 (r=0.707; p-value<0.001). We can then deduce from this analysis, the predictive equation of S-PEF (L/min) based on FEV1 (L/s): S-PEF = 52.975 + 107.646 FEV1.

Among girls, we found a strong positive correlation between S-PEF and FEV1(r=0.86; p-value<0.001). We can deduce from this analysis, the predictive equation of S-PEF based on FEV1: S-PEF= 23.963 + 125.188 FEV1.

[Table/Fig-5] shows multiple correlation coefficients (R); determination coefficients (R^2); Standard Error of Estimate (SEE); Residual Standard Deviation (RSD) for regression equations of F-PEF, S-PEF, FEV1 in boys and girls.

DISCUSSION

In our study, we established new predictive equations of F-PEF, that can be used to calculate theoretical values of PEF in Moroccan children. To our knowledge this is the first study to establish PEF reference values in a cohort of Moroccan children aged between three and 13 years. We compared PEF values measured by peak flow meter and spirometer, and also PEF with FEV1.

Our study took place in the city of Ksar el-Kébir located in the Northern Morocco. Two studies confirmed genetic similarities between Moroccan ethnicities [6,7]. The majority of similar studies took place in different cities at different altitudes [8-14].

Altitude influences lung function. Gupta S et al., compared 290 school children living in altitude (2,150 m) with 280 children (age and sex matched controls) living in 278 m altitude, and they found that the mean peak expiratory flow rate value of children at high altitude was significantly higher than those in plain areas [15]. Ksar El Kebir's altitude is very close to sea level (17 m), eliminating effects of high altitude on respiratory function.

Our study consisted of school children pursuing regular education who were not involved in any professional work. A study done by Das B et al., included 300 children (100 agricultural workers, 100 construction workers and 100 controls), that showed the mean PEF values for workers were lower than controls, especially in construction workers [16].

All information was recorded by a single person to avoid interpersonal bias in our study. Also, the exclusion of children not or badly cooperating with maneuvers, or carriers of respiratory or cardiac affections helped establish predictive equations without bias.

The size of our sample (n=222) was in line with few previous studies done on children [8,13]. Our study included 122 boys and 100 girls, showing slight predominance of boys which was similar to other studies [9-11]. The Iranian study carried out in 2006 included 525 boys and 525 girls [12]. A study of Saudi Arabia by Al-Dawood K et al., included only boys [14].

Our sample consisted of children with the average age of 7.13±1.95 years. A study done by Mohammadzadeh I et al., on a sample of 1,050 children with a mean age of 10.26 years, which is comparatively more than the mean age of the present study [12].

Our sample comprised of children with their height ranging from 99 cm to 172 cm. The mean height was 123 cm in boys and 120 cm in girls. A study by Mittal S et al., found that 366 Punjabi children aged seven to 14 years had mean height of 142 cm in boys and 138 cm in girls, which is more as compared to our study [17].

Our sample consisted of students weighing between 15 kg and 64 kg. The average weight was 26.12±8.15 kg where 55% had a weight between 31 kg and 40 kg. The mean weight of boys (26.75±8.43 kg) and girls (25.35±7.77 kg) was similar to a study done by Sharma R et al., in India. It included a sample of 303 students (163 boys and 140 girls) in the age group of five to 14 year old, with an average weight of 25.61 kg (10-56 kg) in boys and 23.9 kg (9-61 kg) in girls [18].

The level of physical activity, temperature, altitude, ethnic differences, and environmental conditions can affect important determinants of lung functions such as age, sex, height and weight [15,16,19,20]. John JM et al., found a significant positive relationship between PEF and other studied variables like age, weight, height, BMI and chest circumference for both boys and girls. But they noted that the correlation was more robust with height and age [21].

This correlation between respiratory values and anthropometric parameters (height and age) in children can be explained by growth. The slightly reduced values in girls when compared with boys can be attributed to physiological or physical differences between them.

Although the measurement of PEF by a peak flow meter is not devoid of criticism, this practice is largely used for follow up of asthma and management of acute attacks. We found a significant difference of PEF between peak flow meter and spirometer measurements; the difference between the mean S-PEF (194 L/min) and mean F-PEF (176 L/min) was 18 L/min (p-value<0.05).

In our study, PEF was correlated with height and age, similar to the results of some studies [8,11-13,22,23]. Radziavicius FR et al., measured PEF in 1,942 children in the age group five to 10 years who were selected from nine public schools and nine private schools of São Bernardo do Campo City, Brazil and found a linear correlation between PEF with height and age in both genders [22]. Several other studies also found a good correlation of PEF with height [9,20,24,25]. Three studies found a correlation of PEF with age, height and weight [17,26,27]. However, the highest correlation was obtained with height.

Our study found a positive correlation between FEV1 in both sexes with age and height. We have also found positive correlations in all combinations between FEV1, S-PEF, and F-PEF in boys and girls (p-value<0.001). As proposed [17], measuring PEF by a peak flow meter, outside lung function laboratories, may indicate the value of FEV1 with good reliability.

LIMITATION

Our study was monocentric, the size of sample was medium, and it used specific brands of peak flowmeter and spirometer. Obesity and nutrition state were not evaluated. Further studies are needed in other parts of Morocco with similar or larger samples, taking into consideration the above limitations.

CONCLUSION

This study has established Moroccan reference values and predictive equations of PEF of urban school children aged between three and 13 year old. It's clear that F-PEF is lower than S-PEF. PEF can be considered a good alternative to FEV1 when a spirometer is not available.

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