ORIGINAL RESEARCH

Peak expiratory flow values are higher in older and taller healthy male children: An observational study

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Abstract

Purpose: Peak expiratory flow (PEF) was measured in healthy children aged five to ten years in order to provide baseline values and to determine correlations between PEF and factors such as gender, age and type of school.

Methods: After the Ethical Committee of Research in Human of the School of Medicine of ABC – FMABC approval, PEF and height were measured in 1942 children between five and ten years old from nine public schools and nine private schools throughout São Bernardo do Campo City. PEF was measured using the Mini-Wright Peak Flow Meter (Clement Clarke International Ltd.) and height was measured using a Sanny professional stadiometer.

Results: Significant differences were found in values for PEF: higher values were seen in older students in comparison with younger students, in males in comparison with females and in students from private schools in comparison with public schools, with average values ranging from 206 L/min to 248 L/min. Linear correlations were seen for PEF values with both height and age (Spearman Coefficient).

Conclusions: Differences were seen for PEF between genders and between types of school, and a linear

correlation was seen for PEF with both age and height in healthy children from five to ten years old.

The majority of lung diseases are characterized by obstruction of the airflow within the tracheobronchial tree. Thus, techniques to estimate the severity of this obstruction are extremely useful for the assessment of patients and in the evaluation of the efficacy of therapeutic measures.¹⁻⁸

There are several tests able to evaluate lung function. To evaluate pulmonary flow, simple tests such as spirometry and peak expiratory flow and more complex and expensive tests like dilution of inert gases, wash-out of nitrogen and whole body plethysmography can be used. Measurement of pulmonary flow does not directly assess lung function, but reduction in flow is associated with pathologic respiratory conditions and can aid in diagnosis and treatment of patients with lung disease.^{3,9}

The measurement of peak expiratory flow (PEF) is a simple, noninvasive, rapid and economical method to assess the strength and speed of expiration, in units of liters per minute (L/min), through a forced expiration from total lung capacity (TLC). It is used to detect a reduction in pulmonary function associated with the narrowing of airways, to assess the efficacy of clinical treatment used for the resolution of airflow limitation.^{3-5,10-13} These measurements are particularly necessary for patients unable to detect airway obstruction as soon as it starts, as in case with children.¹⁰⁻¹³

The measurement of PEF is dependent on thoracoabdominal muscles and the degree of stress generated by the subject evaluated,¹⁰⁻¹³ and since it requires maximal expiration, it is considered less useful in some populations.¹⁴⁻¹⁸ Furthermore, there are limitations associated with the use of spirometry in children¹⁹. Thus, standardization of PEF is of particular importance in pediatric patients.

There are studies which include children aged five to ten years old, as in the Swaminatham *et al.* study in South India and Usuphile with children in Sri Lanka.^{20,22} There are, however, no comparable values for this age group in Brazil. PEF values from children Sri Lanka may not be applicable to children from Brazil, as other studies have shown that PEF values are dependent on race and ethnicity.^{19,21} Data for Brazil is vital to provide baseline information for epidemiological studies and for clinical management and monitoring of children's growth and development. Thus, the aim of this investigation was to measure PEF in healthy Brazilian children from five to ten years of age. Children from both public and private schools were tested in order to determine the effect of socioeconomic level (and concomitant health and physical fitness) on PEF.

Methods

Design

This is a prospective, descriptive study of a sample of convenience. The sample consisted of healthy chil-

dren, aged between five and eleven years old in public and private schools of São Bernardo do Campo, Brazil. The study was approved by the Ethics Committee of Human Research of the School of Medicine of ABC (Protocol No. 029/2005).

São Bernardo do Campo is located in the metropolitan region of Sao Paulo, including a group of cities known as ABC Region. Its surface covers an area of 408 km² and its population in 2008 was estimated in 801580 inhabitants, resulting in a density of 1962.5 km².

Participants

The study population consisted of 2312 children from nine public schools (Peter E. Gardin, E. Lim Thunder, E. Gofredo, E. Geraldo Hipólito, E. Mário Almeida Martins, E. Flaminio Rangel, E. Aldino Pinotti, Anita E. Magrini, Professor Joseph E. Vargas Bueno) and nine private schools (Leonor College, Athens College, College Villa Lobos, St. Charles College, College Paradise Viva College Life, College Terra Mater, Externato Rio Branco, College Maua) in São Bernardo do Campo. Among the participants 1295 were males and 1017 were females between five and ten years old.

Of the 2312 children selected, 370 were later excluded from the study. The criteria of exclusion included lack of cooperation during one of the two measurements, presence of current or previous pulmonary pathology, and those who did not agree to participate in the investigation. Thus, the final sample consisted of 1942 children.

Outcome measures

The study lasted nine months. Each child was evaluated twice, one month apart, and each evaluation was comprised of three measurements. The highest PEF value was chosen from the three measurements for the initial and final PEF values. Measurements were taken in the standing position. The children were instructed and encouraged to perform with maximal effort during

TABLE 1. Distribution by gender and type of school.

Variables	n (%)
Type of school	
Private	1124 (48.6%)
Public	818 (35.3%)
Gender	
Female	832 (35.9%)
Male	1110 (48%)

all steps. Although PEF measurements are effort- and technique-dependent, which is an issue in the evaluation of children, this method is accepted in the literature, and previous investigations support the feasibility of accurate measurement of PEF in children from 5 to 10 years old.^{23, 24}

In addition to the PEF, height was measured by a Sanny professional stadiometer barefoot in the standing position with his or her spine straight, arms at the body line, and eyes looking to the horizon. Information on variables such as gender and age, in completed years, were provided by the family.

The peak flow meter (Mini-Wright Peak Flow Meter Clement Clarke International Ltd.) was used in order to measure the strength and speed exerted by the expiration in units of liters per minute (L/min). This flow meter is portable, durable, easy to handle and made of plastic material.

Data Analysis

Descriptive analysis was conducted for all study variables. Qualitative variables were analyzed in terms of their absolute and relative values. Quantitative variables were evaluated by their values of central tendency and dispersion. The association between qualitative variables was evaluated by chi-square. The homogeneity of variance and normality were verified by the Levene and Kolmogorov-Smirnov tests, respectively. For variables with these two principles satisfactory we used the Student t test, otherwise, we used the Mann-Whitney test. Correlations were evaluated using the Spearman test. In order to obtain a mathematical model to explain the phenomenon we used the multi-

ple regression model. In order to verify if PEF changes with age and to evaluate the reliability of testing children of different ages, we performed intratests, in which we compared PEF in children of the same gender according to age. Children were divided into 12 groups: six male groups (five vs six vs seven vs eight vs nine vs 10 years old groups) and six female groups (five vs six vs seven vs eight vs nine vs 10 years old groups) and Analysis of Variance (ANOVA) for repeated measures followed by post hoc pairwise multiple comparisons Tukey test were used to assess significance. The level of significance was 5% (statistical package used was SPSS 16.0 for Windows).

Through the multiple regression analysis, we used an estimative formal equation model of PFE values for boys (A) and girls (B):

$$\text{PFE} = 134.989 + (240.73 \times \text{HEIGHT}) + (6.131 \times \text{AGE}) \quad (\text{A})$$

$$\text{PFE} = 162.152 + (264.807 \times \text{HEIGHT}) + (6.709 \times \text{AGE}) \quad (\text{B})$$

Results

We evaluated 2312 healthy children, among them 1295 (56.1%) were male and 1017 (43.9%) were female. Regarding the distribution of schools, 1309 (56.7%) attended public schools and 1003 (43.3%) belonged to private network, as described in Table 1.

Tables 2 and 3 summarize the age, height and initial and final PEF in children from private and public schools in São Bernardo do Campo. There was no significant difference between initial and final PEF. Furthermore, no correlation was observed between PEF variability and age or height in boys and girls. Our results show that boys had higher PEF values in comparison with girls ($p < 0.001$). As shown in Table 3, we observed higher PEF values in children from private schools in comparison with children from public schools in São Bernardo do Campo ($p < 0.001$).

By applying the Spearman coefficient test we found significant dependence of PEF on age and

TABLE 2. Description according to age, height, and initial and final PEF with respect to gender.

Variables	Minimum-maximum		Mean (standard error)		Test
	F	M	F	M	
Age (years) ¹	5-10	5-10	7.9(1.4)	7.9(1.4)	p=0.40
Height (metres) ²	1.05-1.65	1.03-1.63	1.3(0.1)	1.3(0.1)	p=0.25
PEF I (L/min) ¹	100-290	140-410	206(38.1)	240(44.8)	p=0.11
PEF F (L/min) ¹	110-370	160-410	218(38.9)	248(43.5)	p=0.23

PEF I – Initial Peak expiratory flow

PEF F – Final Peak expiratory flow

F – Female

M – Male

¹Mann-Whitney test; ²Student t-test

TABLE 3. Description according to age, height, and initial and final PEF for the type of school.

Variables	Minimum-maximum		Mean(standard error)		Test
	Private	Public	Private	Public	
Age (years) ¹	5-10	5-10	7.8(1.4)	8(1.5)	p=0.11
Height (metres) ²	1.05-1.63	1.03-1.65	1.3(0.1)	1.3(0.1)	p=0.89
PEF I (L/min) ¹	160-410	100-290	254(41.2)	205(36.4)	p=0.14
PEF F (L/min) ¹	180-410	110-300	262(40.5)	216(36.2)	p=0.37

PEF I – Initial Peak expiratory flow

PEF F – Final Peak expiratory flow

F – Female

M – Male

¹Mann-Whitney test; ²Student t-test

TABLE 4. Spearman's correlation coefficient for differences in PEF values with respect to gender.

Variable	Female		Male	
	Initial	Final	Initial	Final
Age (years)	0.759*	0.752*	0.674*	0.687*
Height (metres)	0.755*	0.770*	0.703*	0.747*

*p≤0.05

height corresponding to gender and type of school (Tables 4 and 5, respectively).

Tables 6 and 7 show, through multiple regression analysis, the mean value of PEF according to age and height in children evaluated in both sexes. We also noted a linear relationship between PEF and both age and height: PEF was higher in males in comparison with females.

In order to evaluate the quality control of testing and to better investigate Spearman coefficient test, we performed a comparison among children of the same gender according to age. Children were separated into 12 groups; each group was separated by age and gen-

TABLE 5. Spearman's correlation coefficient with the type of school.

Variable	Female		Male	
	Initial	Final	Initial	Final
Age (years)	0.814*	0.814*	0.844*	0.833*
Height (metres)	0.754*	0.788*	0.781*	0.799*

*p≤0.05

der (five vs six vs seven vs eight vs nine vs 10 years old groups for boys and girls). There was no significant difference among all groups.

Discussion

In this investigation PEF was measured in healthy children from five to ten years old to determine if PEF was influenced by type of school and gender. PEF was used as a simple test to assess pulmonary function, rather than the more complex and expensive tests such as dilution of inert gases, nitrogen wash-out and whole body, which allow the indirect evaluation of the lung function.^{3,9} This study showed that there were

TABLE 6. Mean values of PEF in male children (5-10 years old).

Height (meters)	1.03	1.13	1.23	1.33	1.43	1.53	1.63
Age (years)							
5	144.1	170.6	197.1	223.6	250.1	276.5	303.1
6	150.8	177.3	203.8	230.3	256.8	283.3	309.7
7	157.6	184.1	210.5	237.1	263.5	289.9	316.4
8	164.3	190.7	217.2	243.7	270.2	296.7	323.1
9	170.9	197.5	223.9	250.4	276.9	303.4	329.9
10	177.7	204.2	230.6	257.1	283.6	310.1	336.6

PEF – Peak expiratory flow (L/min)

TABLE 7. Mean values of PEF in female children (5-10 years old).

Height (metres)	1.05	1.15	1.25	1.35	1.45	1.55	1.65
Age (years)							
5	148.4	172.5	196.6	220.6	244.7	268.8	292.9
6	154.6	178.6	202.7	226.8	250.8	274.9	299.1
7	160.7	184.8	208.8	232.9	256.9	281.1	305.1
8	166.8	190.9	214.9	239.1	263.1	287.2	311.3
9	172.9	197.1	221.1	245.2	269.2	293.3	317.4
10	179.1	203.2	227.2	251.3	275.4	299.4	323.5

PEF – Peak expiratory flow (L/min)

significant differences of PEF in relation to gender and with respect to the type of school assessed (public or private). In addition, a linear correlation between PEF and both age and height was seen.

During the period of data collection no discomfort of the children was noted – so stress was not an influencing factor in the PEF values. Moreover, three measurements were taken in each evaluation session and the highest PEF value used for further analysis. The measurement of PEF represents a simple, noninvasive, quick and economical test used to assess the strength and speed of expiration in liters per minute (L/min) through a forced expiration from the total lung capacity (TLC).^{3,10-12} Reduction in PEF reflects tightening of airways, and can be used to assess the clinical status and efficacy of treatment for resolution of airflow limitation.^{3, 9-11,15} These measurements are particularly necessary for patients who are unable to accurately and promptly assess their own degree of airway obstruction, as in the case with children.¹⁰⁻¹²

Analysis of PEF data revealed linear correlation between initial peak expiratory flow (PEF I) and final

peak expiratory flow (PEF F) stages with height and age in both genders and groups schools evaluated. Our findings are supported by those of Sagher *et al.*⁶, who evaluated PEF in 339 healthy Libyan children from seven to sixteen years old, and Usuphille *et al.*, who studied 345 southern Indian children from four to fifteen years old and showed an increase in PEF with age and height, suggesting that older and taller children tend to have higher values of PEF.²² Thus, there is agreement among several published studies from different parts of the world, such as those of Wille and Svensson, Bandopadhyay *et al.*, Swaminathan *et al.*, Siersted *et al.*, Cowie *et al.*, Souef and Cotton *et al.*^{1,2,14,15,20,26,27} In addition, to determine if PEF varies with age and to estimate the reliability of our study, intratests were performed, in which PEF in children of the same gender were compared according to age. No significant influence of age on PEF values was noted, which supports the measurement reproducibility of our method.

Not surprisingly, PEF I and PEF F were found to be higher in boys compared to girls (see Table 2). This

is consistent with the report of Hsu *et al.*, which studied 301 children and showed a strong influence of gender on PEF.²⁸ Pederson pointed out that this difference in PEF values between the genders occurs due to differences in lung size, lung capacity and strength of respiratory muscles.²⁵ This finding is in agreement with previous research in several locations around the world.^{22,25-27}

We believe that the more interesting finding of this study relates to the difference in PEF in children attending private and public schools. To the best of our knowledge, there are no previous investigations that suggest any difference between private and public school regarding lung function. We suggest the following possibilities which may explain this difference: 1) Private school provides more opportunities for children to participate in sports, such as swimming, soccer, volleyball and basketball; hence, improving the children's lung function; 2) Children from private schools may have better medical care in comparison with those from public schools due the better financial support from their family and this better medical care contributes to better respiratory health; and, 3) Children from private schools may have better nutrition, another key factor involved in children health.

No statistically significant differences were seen between initial and final PEF. Furthermore, no association between this PEF and age or height in boys and girls was seen. To the best of our knowledge, there have been no studies that describe positive association between PEF and age or height in children.

Other important factors not evaluated in our study may influence PEF. For instance, Zverev observed in 480 Spanish children from four to seventeen years old, that the average PEF value for females was 310 L/min and for males was 345 L/min.¹⁶ In this present study, the average PEF was 212 L/min for females and 244L/min for males, perhaps reflecting differences in PEF due to race and ethnicity, as previously reported by Tsanakas *et al.*¹⁹

Our investigation presents some limitations. Conventional reference value equations usually list height, age and gender as independent determinants.²⁹ Other possible variables, not tested in our study, include obesity, body mass index, ethnicity and nutrition state.^{30,31} Two series of measurements were made, one month apart, and this could have lead to some experimental error; however, previous studies have also used two measurements and no significant differences between final and initial PEF were found, suggesting no significant influence of learning on PEF.^{23,24}

In conclusion, we observed significant differences between mean values of PEF in relation to gender and type of school assessed (public or private). We also noted a linear correlation of PEF with age and height.

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