The standard range of peak expiratory flow rates of Korean children

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Summary

Background: **The importance in asthma management of monitoring of peak expiratory flow rate (PEFR) has been emphasized.**

Objective: **For effective asthma management in Korean children, we established reference ranges for the PEFR in children 4–18 years of age.**

Methods: **The Mini Wright Peak Flow Meter (MWPFM) and spirometry were used in this study. All tests were conducted using a standardized method recommended by the American Thoracic Society.**

Results: **From a total sample of 2,389 children, 826 (34.5%) were excluded based on our exclusion criteria. For both sexes, the PEFR increased with height, age, weight, sitting height and body surface area (BSA). Height and BSA were found to be better predictors of PEFR than the other parameters. The correlation coefficient between FEV_1 and PEFR using the MWPFM was 0.886 (p < .001). The reference values of PEFR for height in our study were higher for both sexes than for those previously reported in Korea (p < .005). When we compared our results with those from other countries, the values for boys of the same height were lower than those for European children, but higher than those for African and Turkish children (p < .001).**

Conclusions: **We have established reference values for PEFR obtained by MWPFM in Korean children in Seoul, and have provided the percentile curves for PEFR as a function of height to assist clinical practices in treating children with asthma in Korea.** ***(Asian Pac J Allergy Immunol 2011;29:143-9)***

Key words: *peak expiratory flow rate, reference values, asthma, Asian continental ancestry group, child*

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Submitted date: 6/12/2010
Accepted date: 16/3/2011

Introduction

Current asthma guidelines emphasize the importance of pulmonary function studies to diagnose and assess the severity of asthma in patients over 5 years of age. The ease and simplicity with which PEFR can be obtained without the expensive equipment and strict supervision required in measuring FEV_1 and $FEF_{25–75\%}$ makes PEFR a practical alternative to FEV_1 and $FEF_{25–75\%}$ for “home monitoring” of changes in lung function, which has been recommended as an important part of asthma self-management plans by the National Asthma Education and Prevention Program (NAEPP).

NAEPP guidelines have recommended using “personal best PEFR” which is defined as the highest PEFR from daily measurements over 2 weeks rather than the population-based PEFR.[1] However, physicians do not have enough information on a patient’s history of asthma to assess their condition at the first visit and find it difficult to obtain reliable “personal best PEF” data in the early stages of an asthma action plan without using the population-based PEFR. Thus, it is imperative to establish a population-based PEFR that serves as the reference for establishing a reliable personal best PEFR.

Pulmonary function is influenced by ethnicity, age, gender and environmental factors including nutrition, physical activities, pollution and economic status.[2–5] Hence it is necessary for each country to have its own normal PEFR range. There have been previous studies of normal PEFR values in healthy Korean children,[6–8] but the lack of proper reference ranges for PEFR has limited their clinical usefulness, meaning that most pediatricians in Korea use the common international reference.

The objective of this study was to evaluate the most important biometric variables correlated with PEFR and to establish a reference range of PEFR for clinical use in healthy Korean children aged 4–18.

Methods

Sample Characteristics

We evaluated 2,389 children (1,190 males, 1,199 females), from 4 to 18 years of age, living in Seoul, Korea between April and May of 2005. Sample size was calculated from a previous study.[8] The children were recruited from four childcare centers, two elementary schools, one middle school and two high schools. Consent was obtained from the parents, who also completed a questionnaire on the child's medical history. Samsung Medical Center Institutional Review Board (Seoul, Korea) approved the study protocol.

The selection of the reference population was made using the following criteria: without i) acute or chronic lung diseases, ii) history of asthma, iii) history of smoking, iv) history of cardiovascular diseases, and v) acute upper airway infection during the previous 3 weeks.

Anthropometric Measurements

Measurements of height, weight and sitting height were performed by trained teachers at the participating schools on the same day. Body surface area (BSA) was calculated using Mosteller's formula.[9] Height, weight and sitting height were measured without shoes and with light clothing. Height and sitting height were measured using the metal anthropometer and read to the nearest millimeter. Sitting height was measured from the vertex of the head to the base of the seat while the child was in an upright sitting position.

PEFR and FEV_1 Measurements

All tests were performed in the morning by the same experienced technician, and according to the standardized method recommended by the ATS.[3] Proper use of the MWPFM and spirometer were demonstrated to the children with an instructional video. Each child was instructed to take a deep breath, secure the mouthpiece with their teeth, make a tight seal with their lips and blow out quickly and forcefully into the instrument. It is also important during the test to maintain the mouthpiece horizontally and not to obstruct the airway by flexing the neck. All tests were carried out standing, and each subject was allowed a minimum of three attempts. The highest reading was recorded as the PEFR for the subject.

PEFR was measured by Mini Wright Peak Flow Meter (MWPFM; Clement Clarke International, Harlow, UK) and FEV_1, FVC and PEFR by a MicroPlus spirometer (Micro Medical Ltd, Rochester, Kent, UK). We used the MWPFM at a range of 60 to 800 L/min for children aged 7–18 and a range of 50 to 400 L/min for children aged 4–6. PEFR and FEV_1 were also measured by spirometer, with a break of at least 10 minutes between measurements of MWPFM and spirometry. For the 4–5-year age group, highly experienced pediatricians gave the instructions to each child. At the time of testing, each child was given an explanation of the test procedure and several training attempts using computer game incentives (candle, balloon) before the 30-minute test. We obtained flow–volume and volume–time loops with forced expiration lasting more than one second, ensuring that the volume–time trace reached a horizontal plateau for quality control in the test.[10,11]

Statistical Analysis

The reference values and ranges of PEFR were constructed as a function of variables including gender, height (cm), age (years), BSA (m^2) and sitting height (cm). PEFR values were log transformed. The reference values were estimated using the polynomial regression model of PEFR and each variable. Assumptions for the regression analysis and outliers were investigated with a residual analysis. The reference ranges were also fitted to the polynomial regression model of the standard deviations of the residuals for each variable. The coefficient of determination (R^2) for each variable was calculated for goodness of fit to the reference value. Spearman's correlation analysis was done to examine the relationship of PEFR measured by MWPFM with the spirometric PEFR and FEV_1. A p value of $< .05$ was regarded as significant. In order to compare the PEFRs from our study with those of earlier investigations, we used the Wilcoxon signed rank test. A p value of $< .05$ was regarded as significant. The data were analyzed with SAS software (version 9.13; SAS Institute, Cary, NC, USA).

Results

Of the total sample of 2,389 children, 826 (34.5%) were excluded based on our exclusion criteria: upper respiratory infection in the previous three weeks was noted in 656, tuberculosis in one,

Table 1. Age, Sex and anthropometric data in 1608 healthy Korean children living in Seoul

Age	No.		Height (cm, SD)		Weight (kg, SD),		BSA (m^2, SD)	
(years)	M	F	M	F	M	F	M	F
4	34	38	106.59(3.74)	105.93(5.22)	17.79(1.58)	19.02(6.75)	0.73(0.43)	0.74(0.12)
5	33	35	113.31(4.36)	110.13(7.73)	21.19(2.83)	19.52(2.60)	0.81(0.69)	0.77(0.63)
6	24	27	120.40(5.05)	119.06(4.38)	24.42(4.33)	22.23(2.50)	0.90(0.91)	0.86(0.59)
7	30	35	125.62(5.76)	122.96(6.96)	27.75(5.30)	25.76(5.06)	0.98(0.11)	0.92(0.16)
8	50	31	129.84(4.88)	132.50(4.92)	30.10(6.70)	33.28(7.64)	1.04(0.12)	1.10(0.14)
9	46	33	135.58(4.77)	136.93(6.40)	35.48(7.83)	34.13(7.85)	1.15(0.14)	1.13(0.14)
10	44	54	141.74(6.93)	143.25(6.92)	39.34(10.56)	37.48(7.63)	1.24(0.18)	1.22(0.15)
11	52	54	146.58(6.28)	148.00(6.22)	43.48(9.11)	42.91(10.09)	1.32(0.15)	1.32(0.17)
12	83	63	158.59(8.40)	154.10(5.54)	52.28(12.17)	46.89(6.24)	1.50(0.20)	1.41(0.11)
13	54	46	163.71(7.04)	157.93(4.49)	55.17(10.61)	48.78(7.36)	1.58(0.17)	1.46(0.12)
14	49	42	169.51(5.31)	159.71(3.80)	63.51(11.01)	50.83(5.60)	1.72(0.16)	1.50(0.95)
15	101	95	171.20(5.07)	160.41(5.20)	64.32(12.23)	52.68(7.40)	1.74(0.17)	1.53(0.12)
16	69	105	173.30(4.93)	161.33(5.37)	64.10(12.30)	55.61(9.61)	1.75(0.17)	1.57(0.14)
17	104	116	173.65(5.58)	161.70(5.19)	66.26(12.58)	55.70(8.22)	1.78(0.17)	1.58(0.17)
18	22	39	172.05(4.16)	161.83(4.63)	68.22(12.91)	57.52(8.71)	1.80(0.17)	1.60(0.13)

Data shows mean (standard deviation)
BSA, body surface area

bronchial asthma (physician diagnosed) in 109, smoking in 107 and difficulty with cooperation in 29. More than two reasons for exclusion were found in 76 individuals. Thus, the final reference population consisted of 1,608 healthy children, 795 boys and 813 girls (Table 1).

In both boys and girls, PEFR increased with height, age, weight, sitting height and BSA. The height and BSA were found to be better predictors of PEFR than age, weight or sitting height for both sexes. In boys, height showed the best concordance (R^2 = 0.81), followed by BSA, weight and sitting height. In girls, height and BSA showed the best concordance (R^2 = 0.76), followed by weight and sitting height in that order. We obtained the smoothed percentile curves for PEFR according to height in boys and girls (Figure 1 and 2). Boys had higher PEFR values than girls of the same age, height and BSA (p < .005).

Using Spearman's correlation, PEFR measured by MWPFM correlated very well with the spirometric PEFR (r = 0.996). It also correlated well with FEV_1 (r = 0.886) and this was significant (p < .001).

The reference values of PEFR for height obtained in this study were higher for both sexes than those reported in previous studies published in Korea[7,8] (p < .005). We compared our results with those reported from five other countries (Figure 3.). For boys of the same height, the mean MWPFM values for Korean children were lower than the mean values for Mediterranean white children[12] and Sri Lankan children[13] (p < .001), but not significantly different from those for British children[5] (p = .263). However, our mean values for boys were higher than the mean values for Turkish children[14] and Nigerian children[15] of the same age and height (p < .005). For girls, our mean values were lower than the mean values for white Mediterranean girls[12] and Sri Lankan children[13] (p < .005), not significantly different from Turkish children[19] (p < .638) and higher than those for Nigerian children[15] (p < .005).

Discussion

PEFR can be employed as an easy, inexpensive method for home monitoring of asthma. Although compliance with self-monitoring of PEFR varies, it can be a helpful objective tool for the self-management of asthma.

In several studies, height is regarded as having a strong influence on the development of pulmonary function in children.[5,12,13] We also found height to be the most relevant variable for both sexes in predicting PEFR. Biometric variables such as BSA and age were also found to have an effect on the PEFR. Since height can be routinely measured much more easily and accurately than BSA, we provided the smoothed percentile curves for PEFR according to height in boys and girls (Figure 1 and 2). The smoothed percentile curves can be easily used by physicians to assess lung function and employed as a useful tool for the longitudinal assessment of Korean children with asthma.

Our study showed a good correlation between PEFR and FEV_1, which agrees well with several previous reports in asthma patients[16–18] and indicates that measuring the PEFR can be a reliable, useful tool for evaluating respiratory flow and self-management of asthma.

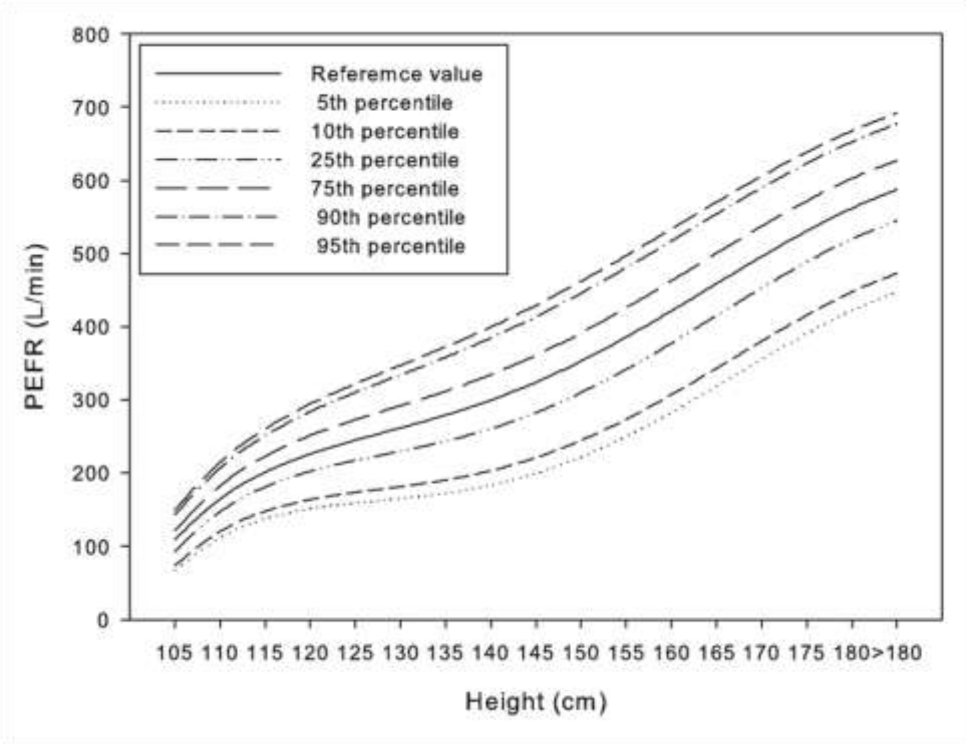

Figure 1. The smoothed percentile curve of PEFR and height in boys living in Korea

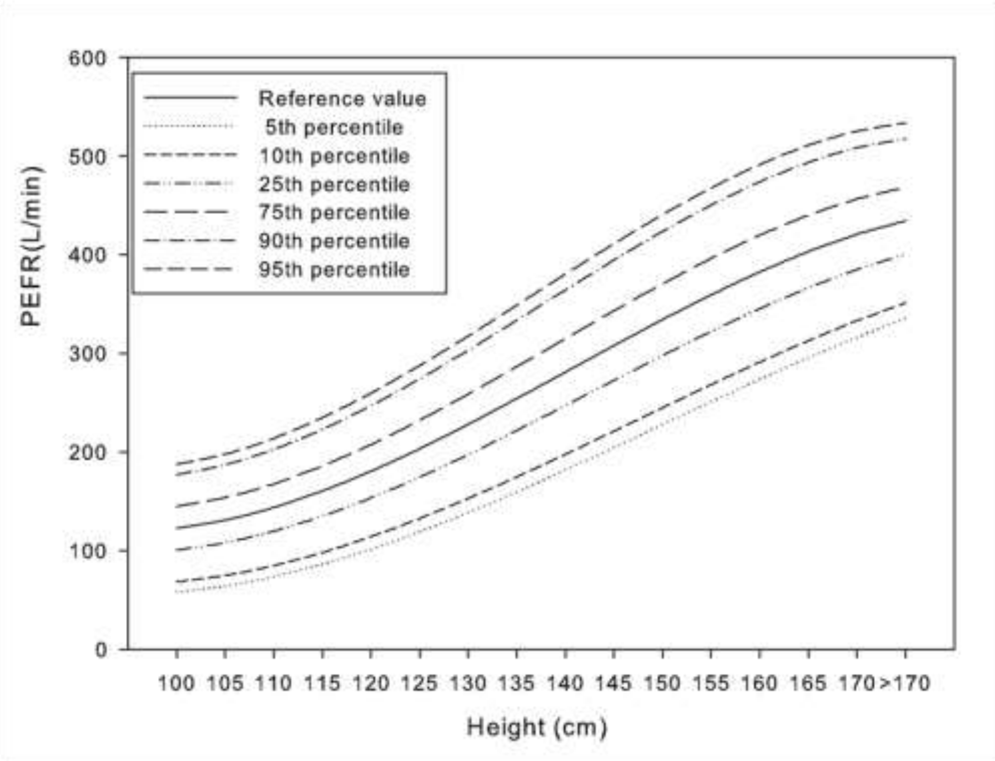

Figure 2. The smoothed percentile curve of PEFR and height in girls living in Korea

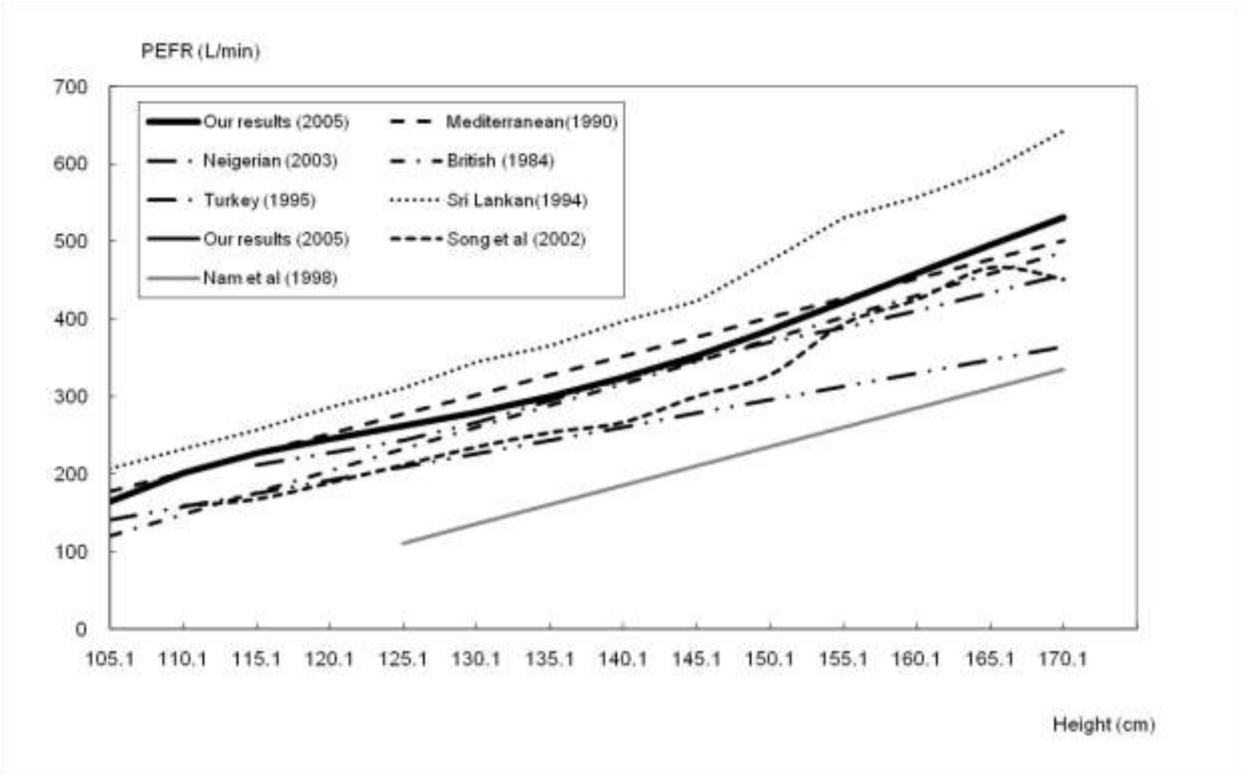

Figure 3. Comparison of our PEFR reference values and those of from previous Korean and other countries in boys

It had been thought that children under six were unable to perform pulmonary function tests, but recent studies showed that it is possible to carry out lung function testing in this age group.[15,16,19,20] In our study, 92 of 232 children aged 4–5 years were excluded because of upper respiratory infections during the previous 3 weeks, but they performed well in the pulmonary function test. Only 27 children out of 232 could not exhale for longer than one second, thereby failing the test: this is a similar failure rate to previous studies performed in the United Kingdom[11] and Taiwan.[19] Our results indicate that Korean children aged between 4 and 5 have the ability to perform the lung function test.

When our results in Korean children were compared with those from other countries,[5,12–15] some differences were noted. Comparisons of boys of the same height showed that our results were lower than those of white European children and Sri Lankan children, but higher than those of African and Turkish children. These differences are likely to be due to racial and socioeconomic variation, but it should also be considered that the tests were done at different times. Thus, the differences may be the result of not only environmental factors but also methodology and sampling variability. Hsu et al.[21] have reported significant differences in lung function between Mexican-American, Caucasian, and African-American children. The African-American boys had the lowest lung function, and the Mexican-Americans had the highest. Western populations, including European and American children, have higher total lung capacity and PEFR than Asian children because of a larger chest dimension and inspiratory muscle strength or lung compliance.[20,21] Further, effects of socioeconomic status on the physical growth and nutrition of children may affect lung function.[22–25]

The reference values of PEFR as a function of height obtained in this study were higher than values reported in previous studies in Korea (Figure 3).[7,8] For the reasons outlined below, we concluded that our study is more reliable than previous Korean studies[6–8] and can be used as a normal reference for children aged 4–18 years. Firstly, in our study a large number of asymptomatic healthy children, who were almost evenly distributed by age and sex, were included. A study on PEFR in Seoul conducted by Nam et al.[7] considered only 452 children aged 8–18 years who were chosen from those visiting the hospital for regular checkups. This small sample size and lack of diversity of the sample in terms of location makes the result unsuitable for use as a representative PEFR. Song et al.[8] performed the tests on a larger sample size, 1,317 children aged 6–15 years, but the children were recruited from one specific region of Seoul, Seongbuk-gu, and so were lacking in sample diversity. Secondly, a high rate of correlation (r = 0.967) for both males and females was achieved when PEFR values by MWPFM were compared with spirometric PEFR. No previous PEFR research for Korean children has investigated the correlation between PEFR by MWPFM and spirometric PEFR in more than 1,000 samples. Thirdly, the procedures were demonstrated to the children by trained pediatricians and technicians prior to the tests being carried out, using an instructional video and several exercises until the children were well aware of and accustomed to the test procedures. This ensured that the tests were performed as per the recommended protocols, which contributed significantly to maintaining the reliability and consistency of the test results.

This study had clinical limitations. Air pollution and seasonal variation may affect lung function in atopic and non-atopic children.[26–28] Our study was performed in spring, and Korea has a hot summer and a cold winter. In addition, although Seoul is the biggest city in Korea, there might be differences between values obtained in Seoul and those obtained in Korean rural areas. Studies in other areas would be useful to show whether the results of our study are representative of all Korean children.

In the present study, we provide standard ranges of PEFR for Korean children aged 4–18, obtained with the MWPFM. Height and BSA were found to be the best predictors of PEFR. We provide the smoothed percentile curves of PEFR as a function of height, which can be used as a convenient reference in clinical practice for Korean children.

Acknowledgements

This study was supported by Outstanding Fellow Award of The Korean Academy of Pediatric Allergy and Respiratory Disease. The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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