Predicted Peak Expiratory Flow: Differences Across Formulae in the Literature

MICHAEL S. RADEOS, MD,*† AND CARLOS A. CAMARGO, JR, MD, DRPH,*

The study objectives were to examine the differences between Peak Expiratory Flow (PEF) formulae in the literature and to assess the potential impact of those differences on the interpretation of clinical guidelines for asthma management. We calculated 100% PEF values for hypothetical patients at the 50th percentile for height and weight and classified the percent predicted PEF into severity groups according to national asthma guidelines. Choosing different formulae could give an 18 year old man a 100% predicted PEF as low as 501 L/min and as high as 730 L/min (delta = 229 L/min); and a 35 year old woman a classification of severe (46%) using one, but moderate (57%) using another. Predicted PEF varied widely across formulae and choice of formula may alter guideline-based care. We propose recently published population-based equations as the reference standard for future asthma guidelines. (Am J Emerg Med 2004;22:516-521. © 2004 Elsevier Inc. All rights reserved.)

The National Asthma Education and Prevention Program (NAEPP) Expert Panel Reports[1,2] recommend use of the Peak Expiratory Flow (PEF) in the assessment and disposition of the asthmatic patients in the emergency department (ED). The algorithm presented in the 1997 guideline classifies asthma exacerbation as: severe (PEF $<$ 50% of predicted value), moderate (PEF 50%-79% predicted), and mild (PEF 80% or greater of predicted). Initial therapy and subsequent disposition are often decided by the resulting classification of asthma severity. An improvement to 70% is considered a "good response" to acute asthma treatment.

The 1997 NAEPP guidelines also encourage use of a "personal best" PEF as an alternative to formula-derived predicted PEF. The guidelines state that the "personal best" PEF may be estimated after a 2- to 3-week period in which the patient records PEF 2 to 4 times per day. The "personal best" is usually achieved in the early afternoon measurement after maximal therapy has stabilized the patient.

There are many different formulae for PEF. The 1991 Expert Panel Report[1] used 2 reference standards for children[3,4] and 2 for adults.[5,6] Three of the studies[3,5,6] were performed on relatively small groups of normal subjects in England, and the fourth[4] actually summarized five studies to compile their predictive equation. All of these reference equations were derived more than 25 years ago from measurements taken by a Wright Peak Flow Meter, except for one group,[6] which derived equations from measurements taken by a Vitalometer and a Wright Peak Flow Meter.

During the past 20 years, there has been increasing recognition that, in addition to age, sex and height differences in PEF, there are lung function differences between subjects from different races. For example, it has been reported that black males have spirometric parameters that are 10-13% lower than white males of European descent.[7] This is assumed to be due to increased leg length to thoracic cavity ratio compared with Europeans. It is understandable that a formula that provides reasonably accurate predictions for white children may overestimate the severity of an of asthma exacerbation in black children. Thus, formulae derived from white children appear not to be generalizable to black children. Use of the older studies should consider this limitation.

Thus, our specific aim was to review reference equations that have been derived from large populations reflecting the heterogeneous population that we treat in United States EDs. We then applied the equations to hypothetical patients to assess how use of the specific formulae might affect guideline-based care.

METHODS

In addition to the reference equations from the NAEPP,[3-6] we ran a Medline literature search, from 1966 to June of 1999, using the following Medical Subject Headings (MeSH): "spirometry" and "reference values." From the list of 340 citations generated, the abstracts were scanned for relevance. Investigations that did not report a PEF prediction equation were discarded. Next, only those studies that included asymptomatic, lifelong nonsmoking subjects and had a total sample of at least 1,000 subjects were reviewed further. Of these, only studies that included black and Hispanic subjects, and were conducted in Western Europe, North America, or Latin America were included.[8-11] This was done to maximize the external validity of these reference values to North American EDs, where whites, blacks and Hispanics account for over 98% of US ED visits.[12] A few studies that had not included blacks and Hispanics were reviewed because of their usage as reference equations by various sources in the past.[13,14] Additional articles were found through manual review of the citations in each of the selected articles.[15,16] Since some of the formulae were calculated as liters per second, we multiplied these by 60 to make all of the formulae comparable.

Using the National Center for Health Statistics estimates of the 50th percentile heights and weights for adults and

From the *Department of Emergency Medicine, Massachusetts General Hospital, and †Channing Laboratory, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA.

Manuscript received June 22, 2003; accepted July 26, 2003.

Presented at the Society for Academic Emergency Medicine Annual Meeting, Boston, MA, May 1999.

Supported by grant no. HL-07427 (to M.S.D.) and grant no. HL-03533 (to C.A.C.) from the National Institutes of Health, Bethesda, MD.

Address reprint requests to Carlos Camargo, MD, EMNet Coordinating Center, Department of Emergency Medicine, 326 Cambridge St, Suite 410, Massachusetts General Hospital, Boston, MA 02114. Email: ccamargo@partners.org

Key Words: Practice guidelines, reference values, peak expiratory flow, spirometry

0735-6757/04/2207-0002$30.00/0
doi:10.1016/j.ajem.2004.08.018

TABLE 1. Predicted Peak Expiratory Flow Rate Equations and Demographic Data from the Included Studies

Investigator	Year of Publication/ Location/Device Used	Subjects*	Race†	Formula‡
Leiner et al[6]	1963 New Jersey, USA Vitalometer + WPFM	n = 155 15-69 years (F 30%)	-	F PEF (L/min) = $[2.93-(0.0072A]H$ M PEF (L/min) = $[3.95-(0.0151A]H$
Godfrey et al[3]	1970 London, UK WPFM	n = 382 5-18 years (F 51%)	W 100%	*F* PEF (L/min) = $5.278H-422.34$ M PEF (L/min) = $5.288H-422.76$
Polgar and Promhadat§[4]	1971 UK, USA, Canada, China WPFM	n = 4,707 4-19 years (F 50%)	-	F PEF (L/min) = $-425.5714 + 5.2428H$ M PEF (L/min) = $-425.5714 + 5.2428H$
Cherniack and Raber[13]	1972 Manitoba, Canada spirometer	n = 1,322 20-69 years (F 34%)	4−	F PEF (L/min) = $60\ [1.13160 - 0.01776A + 0.03594H]$ M PEF (L/min) = $60\ [0.22544 - 0.02403A + 0.05667H]$
Gregg and Nunn[5]	1973 UK WPFM	n = 401 14-64 years (F 50%)	W 100%	F PEF (L/min) = $198.07 + 3.07 - 0.0477A^2 + 1.42H$ M PEF (L/min) = $-30.15 + 30.63A - 0.723A^2 + 0.00521A^3 + 1.46H$
Knudson et al[14]	1976 Tucson, AZ, USA Pneumotachygraph	n = 746 9-80 years (F 61%)	W 100%	F (Age < 20y) PEF (L/min) = $60\ [-3.916 + 0.157A + 0.049H]$ F (Age > 20y) PEF (L/min) = $60\ [-0.735 - 0.025A + 0.049H]$ M (Age < 25y) PEF (L/min) = $60\ [-8.060 + 0.166A + 0.078H]$ M (Age > 25y) PEF (L/min) = $60\ [-5.993 - 0.035A + 0.094H]$
Hsu et al[11]	1979 Houston, USA WPFM	n = 1,805 7-20 years (F 55%)	H 31% W 40% B 29%	F *H* PEF (L/min) = $9.28\times10^{-3}\times H^{2.12}$ W PEF (L/min) = $1.63\times10^{-2}\times H^{2.00}$ B PEF (L/min) = $4.59\times10^{-3}\times H^{2.25}$ M H PEF (L/min) = $8.21\times10^{-3}\times H^{2.15}$ W PEF (L/min) = $3.15\times10^{-3}\times H^{2.33}$ B PEF (L/min) = $2.26\times10^{-3}\times H^{2.39}$
Hsu et al[15]	1979 Houston, TX, USA Spirometer	n = 1,805 7-20 years (F 55%)	H 31% W 40% B 29%	F H PEF (L/min) = $6.97\times10^{-4}\times H^{2.64}$ W PEF (L/min) = $2.58\times10^{-3}\times H^{2.37}$ B PEF (L/min) = $5.51\times10^{-4}\times H^{2.68}$ M H PEF (L/min) = $7.69\times10^{-4}\times H^{2.63}$ W PEF (L/min) = $3.35\times10^{-4}\times H^{2.79}$ B PEF (L/min) = $1.74\times10^{-4}\times H^{2.92}$

TABLE 1. Predicted Peak Expiratory Flow Rate Equations and Demographic Data from the Included Studies (Continued)

Investigator	Year of Publication/ Location/Device Used	Subjects*	Race†	Formula‡
Roca[16]	1986 Barcelona, Spain Spirometer	n = 1,044 15-75 years (F 49%)	H 100%	F $PEF (L/min) = 60 [0.0448H - 0.0304A + 0.3496]$ M M $PEF (L/min) = 60 [0.0945H - 0.0209A - 5.7732]$
Schwartz[10]	1988 USA Spirometer	*n* = 1,963 6-24 years (F 48%)	W 86% B 14%	Children (age 6-11) $PEF (L/min) = 0.06 [e^{(0.95 + 1.45\ln H + 0.23\ln A)}]$ Teens (females ages 12-17) $PEF (L/min) = 0.06 [e^{(0.06 + 1.79\ln H + 0.389\ln A + 0.187\ln BMI - 0.0902)}]$ Teens (males ages 12-20) $PEF (L/min) = 0.06 [e^{(0.06 + 1.79\ln H + 0.389\ln A + 0.187\ln BMI)}]$ Young adults (males ages 18-24) $PEF (L/min) = 0.06 [e^{(4.18 + 1.01\ln H - 0.295)}]$ Young adults (males ages 21-24) $PEF (L/min) = 0.06 [e^{(4.18 + 1.01\ln H)}]$
Pistelli[9]	1992 Central Italy Spirometer	n = 2,176 7-11 years (F 49%)	W100%	F $PEF (L/min) = 0.06 [e^{(1.723+1.324\ln H + 0.0109\ln BMI + 0.388\ln A - 0.061)}]$ M $PEF (L/min) = 0.06 [e^{(1.723+1.324\ln H + 0.0109\ln BMI + 0.388\ln A)}]$
Hankinson et al[8]	1999 USA NHANES III Spirometer	n = 7,429 8-80 years (F 59%)	W 31% B 34% H 36%	F (age < 18y) W $PEF (L/min) = 60 [-3.6181 + 0.60644A - 0.016846A^2 + 0.00018623H^2]$ B $PEF (L/min) = 60 [-1.2398 + 0.16375A + 0.00019746H^2]$ H $PEF (L/min) = 60 [-3.2549 + 0.47495A - 0.013193A^2 + 0.00022203H^2$ F (age > 18y) W $PEF (L/min) = 60 [0.9267 + 0.06929A - 0.001031A^2 + 0.00018623H^2]$ B $PEF (L/min) = 60 [1.3597 + 0.03458A - 0.000847A^2 + 0.00019746H^2]$ H $PEF (L/min) = 60 [0.2401 + 0.06174A - 0.001023A^2 + 0.00022203H^2]$
Hankinson et al[8] cont.				M (age < 20y) W $PEF (L/min) = 60 [-0.5962 - 0.12357A + 0.013135A^2 + 0.00024962H^2]$ B $PEF (L/min) = 60 [-0.2684 - 0.28016A + 0.018202A^2 + 0.00027333H^2]$ H $PEF (L/min) = 60 [-0.9537 - 0.19602A + 0.014497A^2 + 0.00030243H^2]$ M (age > 20y) W $PEF (L/min) = 60 [1.0523 + 0.08272A - 0.001301A^2 + 0.00024962H^2]$ B $PEF (L/min) = 60 [2.2257 - 0.04082A + 0.00027333H^2]$ H $PEF (L/min) = 60 [0.0870 + 0.06580A - 0.001195A^2 + 0.00030243H^2]$

Abbreviations: WPFM, Wright Peak Flow Meter; *F, Female; M, Male; †W, White; B, Black; H, Hispanic; ‡A, age in years, H, height in cm, BMI, weight in kg/cm^2; §Polgar's equations were based on the work of 5 other investigators.

TABLE 2. Variability of 100% Peak Expiratory Flow Rate Across Formulae

Age	Females		Males	
	Mean +/− SD	Range	Mean +/− SD	Range
8 years	234 ± 28 L/min	188-279 L/min	236 ± 30 L/min	184-281
18 years	446 ± 27 L/min	410-503 L/min	583 ± 62 L/min	501-730
35 years	418 ± 28 L/min	386-481 L/min	601 ± 28 L/min	567-639
50 years	395 ± 32 L/min	366-467 L/min	572 ± 31 L/min	531-605

children of various ages,[17] we proceeded to apply the reference formulae to these "average" patients. Although the lower age range for children participating in these studies was as young as 4 years old, not all reference equations studied children this young. Thus, we chose ages 8 and older to decrease the chance of using estimates based on too few subjects. By applying the NAEPP cut points of 50% and 80% predicted PEF to each hypothetical patient, we were able to evaluate whether the change in predicted PEF could lead to a change in guideline classification of acute asthma severity.

Data were analyzed using Excel 7.0 for Windows (Microsoft Corp, Redmond, WA) and are presented as the mean, standard deviation, and range for each formula for 100% predicted PEF in various hypothetical patients. The corresponding predicted PEFs are shown for patients that would be classified as 50% and 80% predicted PEF by recent NAEPP guidelines.[2]

RESULTS

Table 1 describes the demographic characteristics of patients and the formulae from each of the selected studies. The wide range of 100% predicted PEF is presented in Table 2 and is most dramatically shown in the hypothetical 18 year old man, in whom 100% PEF could be anywhere from 501 to 730 liters per minute (mean and standard deviation 583 ± 62 liters per minute).

Table 3 demonstrates the variability of predicted PEF when the various formulae are applied to the 50% and 80% PEF, respectively, based on NAEP guidelines.[1] We chose the 1991[1] table for adults[6] and nomogram for children,[3] as our "reference" formulae. The children's nomogram[3] was chosen instead of the children's table, (4) since the formulae used for this table represent a composite of different investigations, carried out in different countries, by different investigators.[4] Although the numbers were large, this heterogeneity may decrease the validity of combining the equations. For example, a 35-yea-old woman, of average height and weight, who presented with a 50% predicted PEF according to our reference formula,[6] Gregg and Nunn[5] would predict a PEF of 46%-a "severe" exacerbation-while Knudson et al[14] would predict a PEF of 57%-a "moderate" exacerbation.

DISCUSSION

The choice of reference formulae for PEF has implications for those who conduct asthma research, those who design asthma practice guidelines, and primary and emergency care clinicians, who must make treatment and disposition decisions for the individual patient.

TABLE 3. Predicted Percent Peak Expiratory Flow Rate of Various Formulae Based on 50% Peak Expiratory Flow Rate Predicted by Widely Used Adult and Pediatric Formulae

Investigator(s)	Female				Male			
	8 year	18 year	35 year	50 year	8 year	18 year	35 year	50 year
Polgar and Promhadat[4]	52	51	-	-	52	51	-	-
Cherniack and Raber[13]	-	-	57	68	-	-	54	52
Gregg and Nunn[5]	-	47	46	54	-	45	48	47
Knudson et al[14]	58	53	57	68	65	49	53	53
Hsu et al[11]-H/WPFM	46	48	-	-	46	46	-	-
Hsu et al[11]-W/WPFM	47	51	-	-	50	47	-	-
Hsu et al[11]-B/WPFM	50	50	-	-	52	48	-	-
Hsu et al[15]-H	50	45	-	-	48	41	-	-
Hsu et al[15]-W	50	48	-	-	50	41	-	-
Hsu et al[15]-B	52	47	-	-	52	40	-	-
Roca et al[16]	-	52	55	67	-	40	49	48
Schwartz et al[10]	44	44	-	-	44	35	-	-
Pistelli et al[9]	58	-	-	-	55	-	-	-
Hankinson-W[8]	65	54	51	61	63	43	50	48
Hankinson-B[8]	63	53	53	66	68	43	54	54
Hankinson-H[8]	63	53	53	63	63	41	48	48
Mean (+/−SD)	54 (7)	50 (3)	53 (4)	64 (5)	54 (8)	44 (4)	51 (3)	50 (3)

See Table 1 footnotes for abbreviations.

NOTE. Widely used formulae-for adults: Leiner et al[6]; for children: Godfrey et al[3]

TABLE 4. Predicted Percent Peak Expiratory Flow Rate of Various Formulae Based on 80% Peak Expiratory Flow Rate Predicted by Widely Used Adult and Pediatric Formulae

	Female				Male			
Investigator(s)	8 year	18 year	35 year	50 year	8 year	18 year	35 year	50 year
Polgar and Promhadat[4]	83	82	-	-	83	82	-	-
Cherniack and Raber[13]	-	-	92	92	-	-	86	83
Gregg and Nunn[5]	-	75	74	73	-	71	76	75
Knudson et al[14]	92	85	91	93	105	78	85	84
Hsu et al[11]-H/WPFM	74	77	-	-	73	73	-	-
Hsu et al[11]-W/WPFM	75	81	-	-	80	76	-	-
Hsu et al[11]-B/WPFM	80	80	-	-	83	77	-	-
Hsu et al[15]-H	79	73	-	-	76	65	-	-
Hsu et al[15]-W	79	78	-	-	83	65	-	-
Hsu et al[15]-B	83	75	-	-	83	65	-	-
Roca et al[16]	-	83	88	91	-	65	79	76
Schwartz et al[10]	70	70	-	-	71	56	-	-
Pistelli et al[9]	92	-	-	-	88	-	-	-
Hankinson-W[8]	104	86	82	82	102	69	79	77
Hankinson-B[8]	101	84	86	89	109	68	86	86
Hankinson-H[8]	101	84	84	86	102	66	77	76
Mean (+/− SD)	86 (11)	80 (5)	85 (6)	87 (7)	88 (13)	70 (7)	81 (4)	80 (5)

See Table 1 footnotes for abbreviations

NOTE. Widely used formulae-for adults: Leiner et al. ([6]); for children: Godfrey et al. ([3]).

First, the issue of asthma research is affected when investigators attempt to compare studies and outcomes of asthma care based on different reference formulae. As we have seen in Tables 2 and 3, 100% PEF results in widely different absolute values, depending upon which formula is used. Unless we are told that two studies are comparing percent predicted PEF based on the same formula, then we must use caution in interpreting the results. One also must exercise caution when comparing or interchanging different pulmonary function parameters. For example, one investigator cautions the reader that comparing percent predicted PEF to FEV_1 might yield higher values of PEF compared to FEV_1.[18] This may be simply due to the author's choice of the reference equations derived by Knudson et al:[14] Table 3 shows that these formulae give consistently higher predicted values than other PEF formulae. Knudson et al: actually alerted their readers about just this possibility: "Because flow was measured with a pneumotachygraph, the values for instantaneous peak flow obtained in this study, expressed in liters per second, will differ from values obtained with a peak flow meter."[14]

For hospitals (including quality improvement efforts), the lack of a single reference formula, compounded by the lack of interchangeability of formulae, presents a problem. The decision will go to that reference most familiar or easy to use (ie, those with available tables or nomograms). Across hospitals, quality improvement efforts may show wide variability in outcomes, as the severity classifications will not be truly comparable. For example, an institution that uses a PEF formula that estimates a relatively high 100% PEF would place patients into a more severe category than if their PEF had been calculated by a formula predicting a relatively low 100% PEF. This could lead to a scenario in which one ED experiences a higher relapse rate than another ED despite using the "same" PEF cutoff of 70%.

For practicing clinicians, the complexity of the PEF reference equation need not be a concern. Since the resulting formulae can be translated into a simple table or nomogram, then they may be easily used in the busy clinical setting. More important, a single reference allows the clinician to remember only a few PEF values to be able to make an appropriate decision. For example, using the Hankinson equations[8] for a white, 35-year-old man, the cutoff values would be: 492 for 80%, 431 for 70% and 308 for 50% predicted PEF.

While the 1997 NAEPP guidelines encourage the use of a "personal best" PEF as an alternative to formula-derived predicted PEF,[2] we have found, in our experience, that "personal best" peak expiratory flow (PEF) is very unreliable. In one urban ED study, we found that 29% of ED patients "knew" their best PEF.[19] In an investigation of 4,183 ED patients presenting with acute asthma, we found that only 33% could even state their best PEF, and 37% of those who reported a "personal best" PEF exceeded it while in the ED.[19] The choice of formula to select as a standard should satisfy several criteria. First, the population studied should be representative of the patients seen in the ED in terms of age, sex, and race/ethnicity. This increases the generalizability of the formula. Second, the number of subjects should be large so that the estimates of predicted PEF are stable. The confidence interval of an estimate is determined by the standard deviation of the measurement divided by the square root of the sample size. Consequently, the larger the number of subjects tested, the more confidence we can have in the estimated PEF predicted by the formula. Third, the more recently the measurements have been taken, the more likely that it will be that the equipment used in the investigation will be representative of the equipment that continues to be used in current practice. This allows investigators an easier opportunity to reproduce the results.

The Hankinson formulae[8] satisfy the above criteria and would be an ideal reference equation for the United States. Based on NHANES III (Third National Health and Nutrition Survey) from the National Center for Health Statistics, Hankinson and colleagues sampled widely throughout the U.S, to make their equations representative of the greater population. The sample size of 7,429 is much larger than any of the other investigations in our review. The Hankinson formulae would allow us a common language in the objective assessment of asthma exacerbation as well as a solid foundation on which to evaluate and strengthen current clinical guidelines. Furthermore, NHANES conducts ongoing assessments of the health risks among the US population, including spirometry. This ensures a constantly updating reference source.

Although Hankinson and colleagues used a rolling seal spirometer to obtain their measurements, we do not believe that this factor should preclude use of their reference standards for predicted PEF calculations. Since our aim is the standardization of predicted PEF for each guideline decision node, lack of exact agreement between spirometer and peak flow meter is of less importance than a strong correlation between the measures. For example, if the Hankinson equations led to a given age group's predicted PEF being systematically "higher (or lower)" then future guidelines could adjust their cutoff predicted PEFs to reconcile their recommendations to the instruments available in clinical practice.

It is important to note that all formulae probably will perform poorly during puberty due to the large physiological changes and physical growth that occur. Moreover, none of these reference equations addresses patients of Asian or Pacific race/ethnicity. In 1997, this group comprised less than 2% of total ED visits in the US, the latest year for which we have such statistics.[12] This proportion may be higher in different regions of the US, and the proportion of ED patients presenting with acute asthma may also differ. Another difficulty in choosing a reference for this population is its tremendous heterogeneity. Indians, Pakistani, Chinese, and Japanese are only several of the ethnic groups making up this population. The literature includes several reference equations for one or more of these groups. One notable paper actually compares Chinese, Malay, and Indian adults and found spirometric differences between these Asian subgroups.[20]

In summary, there are wide differences across equations for predicted PEF. The choice of formula yields different values and this has important guideline implications. A uniform reference standard would allow for stricter interpretation of current guidelines, allow comparisons of guideline-based care, and provide the physician caring for the patient with acute asthma a more reliable objective criterion for clinical assessment. The equations by Hankinson and colleagues[8] provide a suitable reference standard.

REFERENCES

1. National Asthma Education Program Expert Panel Report: Guidelines for the Diagnosis and Management of Asthma. Bethesda, MD: National Institutes of Health Publication no. 91-3642, 1991
2. National Asthma Education Program Expert Panel Report II: Guidelines for the Diagnosis and Management of Asthma. Bethesda, MD: National Institutes of Health Publication no. 97-4051, 1997
3. Godfrey S, Kamburoff PL, Nairn JR, et al: Spirometry, lung volumes and airway resistance in normal children aged 5 to 18 years. Br J Dis Chest 1970;64:15-24
4. Polgar G, Promhadat V: Pulmonary function testing in children: techniques and standards, Philadelphia, WB Saunders, 1971
5. Gregg I, Nunn AJ: Peak expiratory flow in normal subjects. Br Med J 1973;3:282-284
6. Leiner GC, Abramowitz S, Small M, et al: Expiratory peak flow rate: standard values for normal subjects: Use as a clinical test of ventilatory function. Am Rev Respir Dis 1963;88:644-651
7. Le Souef PN: Paediatric prediction equations for PEF (growth, ageing, gender, race and health). Eur Respir J 1997;10 Suppl 24: 75s-79s
8. Hankinson J, Odencrantz J, Ferdan K: Spirometric reference values from a sample of the general U.S. population. Am J Respir Crit Care Med 1999;159:179-187
9. Pistelli R: Population values of lung volumes and flows in children: Effect of sex, body mass and respiratory conditions. Eur Respir J 1992;5:463-70
10. Schwartz JD, Katz SA, Fegley RW, et al: Analysis of spirometric data from a national sample of healthy 6-24 year-olds (NHANES II). Am Rev Respir Dis 1988;138:1405-1414
11. Hsu KHK, Jenkins DE, Hsi BP, et al: Ventilatory functions of normal children and young adults–Mexican-American, White, and Black: II. Wright peak flowmeter. J Pediatr 1979;95:192-196
12. Nourjah P: National Hospital Ambulatory Medical Care Survey: 1997 Emergency Department Summary; no 304, Hyattsville, MD, National Center for Health Statistics, 1999
13. Cherniack RM, Raber MB: Normal standards for ventilatory function using an automated wedge spirometer. Am Rev Respir Dis 1972;106:38-46
14. Knudson RJ, Slatin RC, Lebowitz MD, et al: The maximal expiratory flow-volumne curve: Normal standards, variability and effects of age. Am Rev Respir Dis 1976;113:587-600
15. Hsu KHK, Jenkins DE, His BP, et al: Ventilatory functions of normal children and young adults–Mexican-American, White and Black: I. Spirometry. J Pediatr 1979;95:14-23
16. Roca J, Sanchis J, Agusti-Vidal A, et al: Spirometric reference values from a Mediterranean population. Bull Eur Physiopathol Respir 1986;22:217-224
17. National Center for Health Statistics: Anthropometric reference data and prevalence of overweight. Bethesda, MD: Vital and Health Statistics. Series 11. No. 238 1976-1980
18. Silverman R, Scharf SM: Pulmonary function testing in the emergency department, in Brenner BE (ed): Emergency Asthma New York, Marcel Dekker, 1999, pp 233–252
19. Diner B, Brenner B, Camargo CA Jr: Inaccuracy of "personal best" peak expiratory flow rate reported by inner-city patients with acute asthma. J Asthma 2001;38:127-132
20. Chia SE, Wang YT, Chan OY, et al: Pulmonary function in healthy Chinese, Malay and Indian adults in Singapore. Ann Acad Med Singapore 1993;22:878-884