General Practice Observed

Peak Expiratory Flow in Normal Subjects

IAN GREGG, A. J. NUNN

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Summary

The relationship between peak expiratory flow (PEF), age, and height has been studied in 202 men and 199 women in south-west London. Strict criteria of "normality" were employed in the selection of the subjects. Multiple regression techniques were used to determine the form of the relationship for each sex. The findings have been compared with those of other authors, and possible reasons for differences include smoking, residence in a polluted area, and incorrect performance of the test.

Introduction

The Wright peak flow meter[1] has been used to test ventilatory capacity in many epidemiological surveys, and in recent years it has been used increasingly by clinicians in outpatient departments, chest clinics, and in general practice. Compared with other instruments which measure ventilatory capacity the Wright meter has several qualities which commend it to clinicians, particularly its relative cheapness, size, independence of electrical power, and the speed with which the test is performed.

Measurement of peak expiratory flow (PEF) is of value for the identification of chronic obstructive bronchitis and for the assessment and follow-up of patients with asthma. For these purposes evaluation of an observed reading of PEF requires knowledge of its range in normal subjects of the same sex, age, and body size. However, there is still much uncertainty among clinicians about normal values of PEF.

This paper reports the findings of PEF in 202 men and 199 women over the age of 14 years who satisfied stringent criteria of "normality." Regression equations have been calculated for the purpose of predicting normal values of PEF. Possible reasons are discussed for differences between our findings and those of other authors.

Methods and Subjects

One of us (I.G.) has carried out a prospective survey in his general practice in Roehampton, London, to determine the effects on ventilatory capacity of smoking, lower respiratory infection, and other factors.[2] Over 1,500 men and 1,000 women over the age of 14 years have been studied. In every case a detailed inquiry was made about past and present smoking habits, symptoms of mucus hypersecretion, previous or continuing liability to wheeze, the occurrence of bronchitis in childhood or adulthood, and a history of other respiratory disease. Ventilatory capacity was measured by the Wright peak flow meter.

Measurement of PEF.—Four meters were used during the survey. At about six-monthly intervals they were returned to the makers for checking of calibration and for servicing. A regular comparison of their calibration was also carried out by I.G., using each meter in turn to measure his own PEF. The purpose and technique of the test was explained to every subject and this was followed by a demonstration of its performance. After one or two trial attempts the subject was exhorted to make a maximal effort and was closely watched to ensure that he or she maintained an airtight seal between the lips and the mouthpiece of the instrument. The highest value of PEF achieved in three successive attempts was recorded. Standing height in inches was measured after removal of shoes.

Selection of Normal Subjects.—The records of all patients who had been studied in the larger survey were examined. Normal subjects were defined as those who fulfilled the following criteria: (1) they had never smoked; (2) they denied that they were subject to recurrent or persistent expectoration; (3) they were not subject to wheeze, nor had had an episode of acute bronchitis; (4) they had not had asthma or recurrent bronchitis during their childhood; and (5) they had not had any serious respiratory disease. In most of the normal subjects PEF had been measured on more than one occasion. For the purpose of this study the first recorded measurement of PEF was used, except in a few cases when the first measurement had been made during an episode of upper respiratory infection.

Results

The age and height distributions of the subjects are shown in table I. There were very few men over 54 years and women over 64 years of age, but otherwise all ages were well represented in both sexes. Multistage stepwise analyses were performed for men and women separately to determine the form of the regression of PEF on age and height. When the data were plotted it became evident that the relation between PEF and age was curvilinear. Therefore, powers of age up to age^4 were included in the regression and the procedure of backward elimination was used to determine the final model. All the variables were initially included and then eliminated in turn if their additional contributon to the regressen sum of squares was not statistically significant. At each stage the variable rejected was the one whose contribution was the smallest.

Brompton Hospital, London SW3 6HP

IAN GREGG, B.M., F.R.C.G.P., Director, Department of Clinical Epidemiology in General Practice, Cardiothoracic Institute

A. J. NUNN, M.SC., Statistician, M.R.C. Tuberculosis and Chest Diseases Unit

TABLE I—*Age and Height Distributions of Subjects in Series*

Factor	Male (n = 202)		Female (n = 199)	
	No.	%	No.	%
Age in years:				
Less than 25	66	33	64	32
25-34	50	25	30	15
35-44	45	22	45	23
45-54	27	13	27	14
55-64	13	6	19	10
65 or more	1	0	14	7
Height in inches:				
Less than 60	0	0	8	4
60-62	1	0	65	33
63-65	11	5	81	41
66-68	57	28	41	21
69-71	83	41	4	2
72 or more	50	25	0	0

When considering the data for males it was found that four factors contributed significantly to the model. These were age, age^2, age^3, and height. Higher powers of age did not significantly improve the model. In the case of females the significant factors were age, age^2, and height. The regression equations and standard errors of the means for men aged 14-54 and women aged 14-64 are shown in table II. The regression curves have been drawn for two heights of each sex in fig. 1. Our findings are compared with those of some other authors, height having been standardized to 69 in (175 cm) in the men and 66 in (168 cm) in the women (fig. 2).

TABLE II—*Regression Equations*

PEF (l/min). = $b_0 + b_1$ age $+ b_2$ age^2 $+ b_3$ age^3 $+ b_4$ height

	Males (aged 14–54)	Females (aged 14–64)
b_0	−30·15	198·07
b_1	30·63	3·07
b_2	−0·723	−0·0477
b_3	0·00521	—
b_4	3·71 in 1·46 cm	3·60 in 1·42 cm
Standard error (mean) (after applying regression)	48 l./min	42 l./min

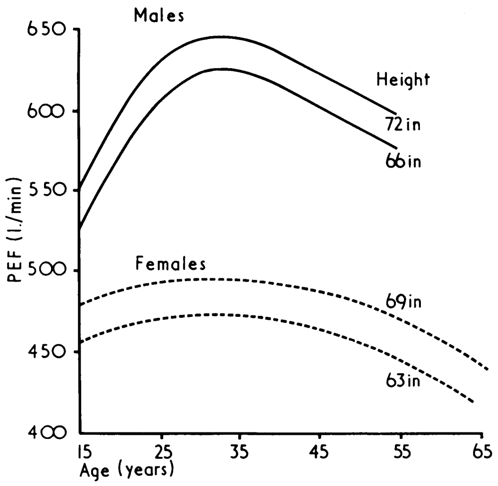

FIG. 1—Predicted PEF for males of height 72 in (183 cm) and 66 in (168 cm) and females of height 69 in (175 cm) and 63 in (160 cm).

Discussion

A preliminary analysis was carried out in 1967, at which time the normal series comprised 98 men and 87 women of

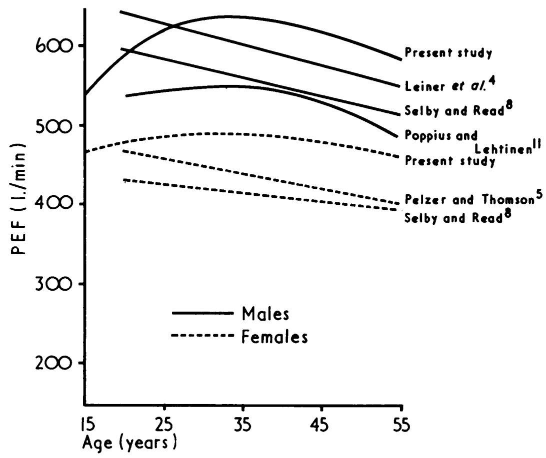

FIG. 2—Comparison of results from present series with those of other authors for males of height 69 in (175 cm) and females of height 66 in (168 cm).

whom none was aged less than 20 years. In calculating the regression equations for PEF on age and height in both sexes it was assumed that there was a linear relation between fall of PEF and increasing age (ref. [3]). A similar assumption was made by nearly all other authors who have published normal values of PEF, including Leiner *et al.*[4] and Pelzer and Thomson[5] whose data for males and females respectively are quoted by Cotes.[6]

Clearly, a linear fall of PEF can occur only after the age at which maximal PEF is attained, and if adolescents are included in the series the shape of the regression must be curvilinear. Our findings suggest that in both sexes PEF does not begin to decline until about the age of 35 years (figs. 1 and 2). Very similar findings were reported by Brooks and Waller,[7] who pointed out that linear extrapolation of the decline in PEF which occurs at older ages back to the age of 20 years gave predicted values which were too high for young adults.

Because our series contained too few men over 54 years of age the regression equation for men is valid only for ages between 14 and 54 years. However, we examined the data of 37 men aged 50 to 76 years who had all given up smoking at least six months previously but who satisfied all our other criteria of "normality." Their PEFs agreed closely with what would have been their predicted values if the regression curves, shown in fig. 1, were extended linearly beyond the age of 55 years, the gradient of fall being about 2 l/min per annum. The regression equation for women is valid for ages between 14 and 64 years.

Though all the factors considered in the regression equations were highly correlated with PEF, they accounted for only a small percentage of the total variation in PEF (22·6% for the male data and 28·0% for the female data). Much of this variation can be attributed to differences of thoracic volume and musculature which are not reflected by differences in standing height. In the course of the survey it was often observed that broad, muscular subjects achieved higher values of PEF than thin but taller subjects of the same age and sex. Similar considerations account for the difference of PEF between the two sexes which emerges at puberty and becomes maximal at about the age of 30 years (figs. 1 and 2).

In both the male and female series the standard error of the mean (table II) was smaller than that found by other authors (table III), which suggests that our strict criteria produced a more homogeneous population. This could also account for the fact that the values of PEF which we found were higher than those of other authors (fig. 2).

TABLE III—*Characteristics of Other Authors' Series Compared in Fig. 2*

Author	Population Studied	No. of Subjects	Age-range (Years)	Standard Error (Mean)
	Males			
Selby and Read[8] ..	Lifelong non-smokers, Sydney	44	18–74	57
Leiner *et al.*[4]	Healthy subjects, East Orange, U.S.A.	105	21–64	70
Poppius and Lehtinen[11]	Healthy forestry workers, Finland	508	20–59	68
	Females			
Selby and Read[8] ..	Lifelong non-smokers, Sydney	56	21–60	52
Pelzer and Thomson[5]	Healthy subjects, London	64	19–82	67

The data from all the other subjects studied by I.G. in his larger survey are currently being analysed to determine the effects on PEF of such factors as smoking, lower respiratory infection, and the liability to wheeze. These and other factors could cause impairment of PEF in apparently healthy subjects and they will be considered here because they may explain some of the differences between the findings of other authors in subjects regarded as normal and our own findings in strictly selected subjects.

All other authors who have published normal values of PEF, with the exception of Selby and Read,[8] included smokers in their series unless they admitted to chronic expectoration or gave a history of previous chest disease. There is evidence, however, that some smokers have a sustained increase in airway resistance even though they deny chronic expectoration. Read and Selby[9] found a significant difference between the regression of PEF on age in male smokers who denied any symptoms and that in men who had never smoked. Zamel and others[10] compared a group of non-smokers with a group of smokers of similar age and sex distribution, all of whom denied expectoration: they found a highly significant difference between the mean PEFs of the two groups.

The normal series of Poppius and Lehtinen[11] comprised healthy Finnish forestry workers among whom excessive cigarette smoking was a common habit. The inclusion of heavy smokers may account for the considerable difference between their findings and ours (fig. 2), though the form of their regression equation resembles our own because they used a similar approach in the analysis of their data. Selby and Read[8] excluded smokers and ex-smokers from their normal series, but they studied only a small number of subjects over a wide age range (fig. 2, table III), most of whom were ambulant outpatients and their accompanying friends.

Residence in areas with high levels of atmospheric pollution has been shown to be associated with impairment of PEF in both non-smokers and smokers,[12] while in children area of residence has a highly significant influence on levels of PEF.[13] Roehampton is a residential suburb in south-west London, which for the past 15 years has been a smoke-controlled zone. Therefore, the effects of atmospheric pollution on the subjects whom we studied must have been less pronounced than on subjects living in many Midland and Northern industrial cities. Flint and Khan[14] reported their findings of PEF in a large sample of apparently healthy subjects in Sheffield. In both sexes the mean PEF was much lower than that found by us and other authors and there was a much steeper fall of PEF with increasing age.

In the survey which I.G. has carried out in his general practice particular care was taken to elicit a history of wheeze or bronchitis, and in the case of adolescents and young adults it was usually possible to verify this from their medical records or by inquiry of their parents. Though other authors excluded from their normal series any person who was subject to typical episodes of asthma, they may have inadvertently included persons who had had mild attacks of asthma or wheezy bronchitis during childhood or subsequently. Jones and Jones[15] showed that reduction of ventilatory capacity may persist for many years in some persons who have previously had asthma but who no longer have any symptoms.

Small departures from the correct technique of performing the test may cause spuriously low values of PEF. Because of the dependence of PEF on the muscular effort exerted in a forced expiration, it is of great importance to persuade the subject to make a maximal effort. Fairbairn *et al.*[16] found that the values of PEF which were obtained by nurses supervising the test were lower than those obtained in the same subjects by doctors who, it appeared, had used greater persuasion. In general, it is more difficult to persuade women to make a maximal effort than men, an observation which was also noted by Fairbairn *et al.*[16]

Provided that the subject performs the test correctly, there should be a close agreement between the values of PEF obtained in three successive attempts. Therefore, it is unprofitable to calculate the mean of the three values. In the normal subjects whom we have studied very little variation was found between measurements of PEF made on different occasions except in young men, in whom a considerable rise of PEF was observed over the course of five or more years. This was consistent with the steep ascent of the regression curve for males between the ages of 15 and 30 years (fig. 1). Temporary falls of PEF were often observed in normal subjects during episodes of upper respiratory infection.

Because of the large standard error of PEF in both sexes (tables II and III) an observed value of PEF up to 100 l./min below the predicted value should not be regarded as being necessarily abnormal. Conversely, an observed value of PEF falling within the normal range does not exclude the existence of a small degree of airways obstruction.

Nomograms for predicting normal values of PEF, derived from the data of this study, have been prepared and are available from Airmed Limited, Edinburgh Way, Harlow, Essex.

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