Peak Expiratory Flow Rates in the Elderly

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While there has been increasing interest in using peak flow meters in medical practice, reference values for white adults aged over 65 years are not available. Peak expiratory flow rate was studied in ambulatory adults aged 65 years and above. Healthy nonsmoking subjects were selected by stringent criteria. Multiple linear regression was used to determine equations predicting healthy peak expiratory flow rates from age and height for each sex. The results are compared with published normal values for younger adults, and the efficacy of using peak flow rates is discussed.

Peak flow meters may be used in primary care office practice in evaluating obstructive airway disease, monitoring asthma management, and determining the need for hospital admission.[1-3] Reference values for peak expiratory flow rate (PEFR) in healthy persons are important both in initial evaluation and in assessing treatment efficacy. Although reference values have been published for persons from childhood through middle age, few studies have examined adults over 65 years of age.

In the United States, commonly cited reference values for older adults have been extrapolated using regression coefficients derived from studies of young and middle-aged adults.[1,4,5] Armstrong Industries, manufacturer of commercial peak flow meters, includes such reference values with its meters. These values are based on Gregg and Nunn's study,[6] which included only 14 women and one man aged over 65 years. Similarly, other vendors have based their reference values on the study by Leiner et al,[7] which included one woman and no men over 65 years.

There is little evidence to support this extrapolation from studies of a younger population. The mechanisms responsible for the age-related decline in all indices of lung function are multiply determined and unlikely to be constant throughout adult life span.[4,8] Cotes[4] recommends that "where it is intended to include older subjects either a curvilinear relationship should be used or the data for the elderly should be treated separately."

The present study gathered PEFR from healthy adults older than 65 years using health criteria similar to "normal" criteria used by Gregg and Nunn[6] and Leiner et al.[7] Regression coefficients are calculated to predict healthy values for PEFR.

METHODS

Two hundred seventy women and 163 men older than 65 years were recruited for the study from 14 senior citizen centers located in the greater Buffalo area during the summer months. These centers included public and private agencies.

A research assistant made one or more visits to each center during the day and asked adults attending the program if they would be willing to participate in the study. Informed consent was gathered, then a brief history was obtained in private according to a structured interview. This interview gathered (1) demographic data (age, race, sex, and height), (2) past medical history of smoking, lung disease, and allergies, (3) current respiratory symptoms, and (4) occupational risk assessment. The research assistant then covertly rated the subjects' mental status based on their conduct in the interview. A Mini-Wright peak flow meter was used to gather three measurements of PEFR, all of which were recorded. Calibration of the meter was checked before and after the study.

Healthy subjects were defined as those reporting (1) no current symptom of wheezing, shortness of breath, cough, or sputum production; (2) no history of asthma, chronic bronchitis, pneumonia, emphysema, lung cancer, tuberculosis, or other pulmonary diseases; and (3) no tobacco use in at least 10 years. All subjects were ambulatory and in apparent good health. Of the 433 subjects recruited, the data of two subjects were eliminated from the study be-

Submitted, revised, February 10, 1989.

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TABLE 1. HEIGHT AND AGE DISTRIBUTION OF HEALTHY SUBJECTS

	Female Subjects (n = 70)	Male Subjects (n = 39)	Total (N = 109)
Height (inches)			
51-53	1	0	1
54-56	2	0	2
57-59	10	0	10
60-62	33	4	37
63-65	20	11	31
66-68	4	19	23
69-71	0	5	5
Age (years)			
65-69	14	10	24
70-74	26	14	40
75-79	17	8	25
80-84	7	5	12
85-89	4	0	4
90-94	2	1	3
95-100	0	1	1

TABLE 2. REGRESSION EQUATIONS FOR THE LINEAR MODELS USING AGE AND HEIGHT TO PREDICT PEAK EXPIRATORY FLOW RATE (PEFR) FOR MEN AND WOMEN OLDER THAN 65 YEARS

Sex	Equation
Women*	$PEFR_{female}$ (L/min) = 514.11129 − 6.37705 age (yr) + 5.23406 height (in.)
Men†	$PEFR_{male}$ (L/min) = 552.07200 − 8.71301 age (yr) + 8.79769 height (in.)

*SE = 66.270
†SE = 105.4434

cause of their mental status score (ie, apparent difficulty in understanding the interview), and the data from one subject was eliminated because of unusually short stature (36 inches). Since ethnic factors have frequently been cited as having significant bearing on measures of lung function, the data from one Asian, two Hispanic, and 22 black subjects were excluded from the analysis, leaving only white subjects.[4,9-16] Of the remaining 405 eligible subjects, 109 were found to be healthy as defined.

RESULTS

Analysis of the demographic data found healthy subjects to number 70 women and 39 men (Table 1). Female subjects ranged in age from 65 to 92 years, with an average age of 74.4 years; male subjects ranged in age from 65 to 95 years, with an average of 74.0 years. The average height of women was 61.6 in. (range: 53 in. to 67 in.); for men it was 66.1 in. (range 62 in. to 71.5 in.).

Multiple linear regression was run separately for women and men. The highest of each subject's three PEFR measurements was used in all analyses. Age and height were added stepwise to the regression model. Regression coefficients for the linear models, including age and height, are presented in Table 2. Age contributed significantly to the regression model for both men and women. Height was retained in the model, since it increased the amount of explained variance by approximately 10%. The expected values for PEFR in healthy adults older than 65 years are presented in Figure 1. The figure shows a marked drop in PEFR from age 65 to 85 years, with men having higher values and a more sharply decreasing slope than women. Taller subjects showed slightly higher PEFR values for both sexes. In Figure 2, results are compared with expected adult PEFR values derived by Gregg and Nunn,[6] who used subject selection criteria similar to those in the current study. Gregg and Nunn's expected values are shown for men aged 15 to 55 years and women aged 15 to 65 years, at heights presented in their paper. Expected values from the current study are shown for men and women aged 65 to 85 years, at the same heights.

To determine the efficacy of these predicted values in discriminating healthy PEFRs from values representing decreased lung function, a series of one-way analyses of variance were conducted comparing the healthy subjects to groups of subjects having a history of specific respiratory disease or specific respiratory symptoms or who currently smoked tobacco. Two dependent measures were used: (1) the difference between a subject's actual PEFR

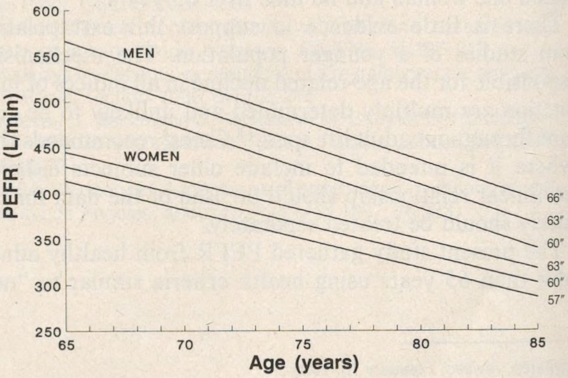

Figure 1. Expected PEFR for men and women of various heights, aged 65 to 85 years.

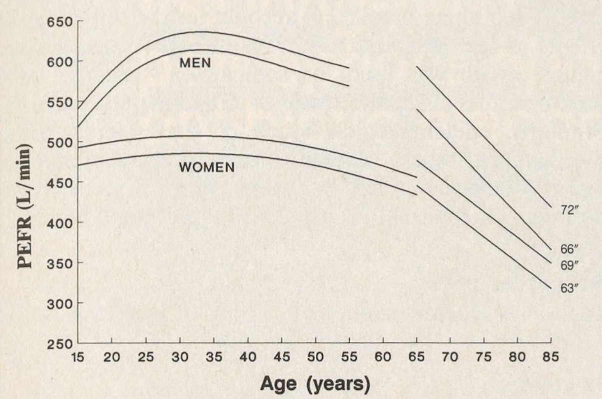

Figure 2. Expected PEFR for men and women of two heights. Results of present study of subjects aged 65 to 85 years compared with those of the Gregg and Nunn study (1973) of those aged 15 to 65 years.

and expected PEFR as predicted by the regression line ($PEFR_{diff} = PEFR_{actual} - PEFR_{expected}$) and (2) the ratio of the subject's actual PEFR to expected PEFR ($PEFR_{ratio} = PEFR_{actual}/PEFR_{expected}$). Results are presented in Table 3. Subjects reporting a history of one or more respiratory diseases showed a significant ($P<.0001$) decrease of approximately 51 L/min in PEFR from expected values (approximately 88% of expected PEFR). Subjects currently experiencing respiratory symptoms showed a mean decrease ($P<.001$) in PEFR of 36 L/min (approximately 92% of the expected value). Subjects currently smoking tobacco were also found to have marked decreases in PEFR.

DISCUSSION

The regression lines determined in this study are closely in line with the results of Gregg and Nunn's[6] previous study of healthy younger adults, as shown in Figure 2. The slope, however, decreases more sharply than predicted by extrapolation of Gregg and Nunn's results. This finding is consistent with the hypothesis that the age-related decline in PEFR is multiply determined and is not constant throughout the adult life span.

The subject selection criteria used were quite similar to those of Gregg and Nunn,[6] with the major difference being that the current study included former tobacco smokers who had not smoked in at least 10 years. These ex-smokers were a minority of the healthy group and had not smoked in 29.2 years, on average (SD = 14.9). The inclusion of such former smokers did not significantly affect the regression coefficients. Among the 109 healthy subjects, correlations between smoking history variables and $PEFR_{diff}$ were small (range in r was −.16 to +.07) and nonsignificant. Lung function improves when smokers quit smoking so that the mortality rates of former smokers who have not smoked in 10 years are very close to the rates of nonsmokers.[17] As noted by Gregg and Nunn,[6] most other studies of PEFR in white subjects used less stringent criteria to select healthy subjects, and thus yielded regression lines with lower overall PEFRs. Studies of other racial and ethnic groups that included a significant sample of subjects older than 65 years have consistently found a trend of decreasing PEFR through the older years.[13,15] While the number of healthy subjects per decade of life in the current study was similar to that used by Gregg and Nunn, the sample size is still relatively small. Replication of this study using similarly stringent criteria is needed, perhaps excluding former smokers as well.

Previous authors have varied in their suggestions for determining abnormal PEFR values, with some recommending use of a percentage of the predicted healthy value equivalent to the current $PEFR_{ratio}$,[3,7] and others advocating simply measuring the raw decrease from the predicted healthy value ($PEFR_{diff}$).[6] The current study compared difference scores with proportional scores in several ways. The overall Pearson product-moment correlation between the two scores for all eligible subjects (including healthy,

TABLE 3. ONE-WAY ANALYSIS OF VARIANCE COMPARING HEALTHY GROUP TO OTHER GROUPS

		$PEFR_{diff}$*			$PEFR_{ratio}$†		
Group	**No.**	**Mean**	**SD**	**P**	**Mean**	**SD**	**P**
Healthy	109	0.0	80.2		0.9984	0.2077	
Diseased	137	−50.6	109.6	<.0001	0.8799	0.2619	<.0002
Symptomatic	255	−36.5	98.0	<.001	0.9162	0.2387	<.002
Smokers	58	−58.0	115.7	<.0002	0.8712	0.2564	<.001

PEFR—Peak expiratory flow rate
Note: Separate analyses are presented for each of the two dependent variables
*$PEFR_{diff} = PEFR_{actual} - PEFR_{expected}$
†$PEFR_{ratio} = PEFR_{actual} / PEFR_{expected}$

smoking, sick, and symptomatic subjects) was .9713 ($P<.0001$), indicating that they are essentially measuring the same activity ($r^2 = 0.94$). As shown in Table 3, comparisons between healthy subjects and all other groups of subjects were virtually identical for $PEFR_{diff}$ and $PEFR_{ratio}$. Thus, the use of either difference or ratio scores is justifiable. The current authors concur with Gregg and Nunn's[6] comments that rigid criteria for determining abnormality should be interpreted carefully. Clearly, the PEFR values of both healthy and respiratory-problem groups show considerable variability, with much overlap of the respective distributions.

These reference values are offered for clinical and research use. For clinical use, it is important to keep in mind that these values, as with those of Gregg and Nunn,[6] represent idealized values of persons in excellent respiratory health. Gregg and Nunn selected 401 persons out of 2500 studied (16%) using their criteria for health. Since the current study only interviewed persons attending senior citizen centers, this initial group was a fairly healthy, active subset of the population. Yet only 27% of those interviewed fit the current health criteria. To not smoke, have no history of pulmonary disease of any kind, and have no current respiratory symptoms is clearly unusual. The appropriate "gold standard" for evaluating PEFR, however, is healthy values regardless of the percentage of the population these values represent. As with weight, blood pressure, serum cholesterol, and other clinically useful measures, the appropriate comparison for evaluating disease processes in an individual is healthy values, not average values for an overweight, nutritionally imbalanced, smoking population.

The healthy values presented here will be useful clinically in assessing the pulmonary status of normal elderly individuals as a part of their regular health maintenance. A clinician using these values could determine whether any elderly individual's PEFR was decaying faster than normal and thus avoid attributing abnormal changes to age-related decay. In following the course of a patient with respiratory problems (eg, asthma), the most important PEFR data would be the individual's change over time. Knowledge of age-related healthy values could also be useful here as well, as they could (1) help determine what a realistic healthy PEFR target might be and (2) indicate that a goal of maintaining current PEFR over years is probably unrealistic, given the decreasing slope of the healthy values. Of course, PEFR measurement is not intended to replace more extensive pulmonary function testing when indicated, but can be useful clinically with the elderly as it is with younger patients.

Research on clinical applications of PEFR in the elderly has been hampered by the lack of healthy reference values. For example, Galasko et al[18] investigated PEFR as an aid in the prognosis of elderly patients undergoing hip operations. Their analysis failed to account for the simultaneous effects of sex, age, and height on PEFR. An unmatched control group was used for comparison "because there were no tables of predicted values of PEFR in the elderly." Similarly, epidemiological study of coal miners, urban dwellers, and others exposed to high levels of pulmonary toxins would be aided by comparison of its subjects' PEFRs to the normal healthy PEFRs presented here.

Acknowledgment

This work was supported in part by Public Health Service grant No. 5D-15PE-82019.

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