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# Peak flow rate in Nigeria:

## Anthropometric determinants and usefulness in assessment of ventilatory function

E. A. ELEBUTE and D. FEMI-PEARSE

*Cardiothoracic Research Laboratory, Lagos University Teaching Hospital, P.M.B. 12003, Lagos, Nigeria*

The inexpensive nature of the peak flow rate (PFR) makes it a suitable test of ventilatory function for use in some parts of Africa, where medical facilities are still poor. In order to establish standard values for PFR in Nigeria, anthropometric measurements, lung volumes, and PFR were obtained from 142 men and 88 women, all of whom were healthy Nigerians. The mean values of PFR were 482·1 l/min ($\pm$83·3) for males (average age 34·9 years) and 385·6 l/min ($\pm$65·7) for females (average age 29·4 years), both means being significantly lower than corresponding means of predicted values calculated from formulae based on previously reported studies of Caucasians. PFR was correlated with age, various physical measurements, and lung volumes. The combination of age and height gave the regression equation for predicting PFR with the lowest standard error of estimates; and virtually all lung volumes measured correlated significantly with PFR. In 16 adult Nigerian asthmatics, PFR correlated significantly with vital capacity, forced expiratory volume (1 second), and expiratory reserve volume; it was highest in those who had no symptomatic or spirometric signs of any ventilatory defect, and lowest in those who had signs of both obstructive and restrictive defects.

There have been few studies of pulmonary function among Africans, almost certainly due to lack of the relatively sophisticated and expensive equipment required. A simple, easy, reliable and inexpensive test of lung function will therefore be useful for both clinical and epidemiological investigations in those parts of Africa where medical facilities are still meagre and rudimentary. The Wright peak flow meter (Wright and McKerrow, 1959) provides such a test. We have tried to establish 'normal' values for peak flow rate (PFR) among healthy adult Nigerians so as to introduce it into clinical practice in Nigeria, and possibly other parts of Africa. Here we present the values obtained from 142 men and 88 women and describe the relationship of these values to the physical characteristics and lung volumes of the subjects studied. Our work was carried out in conjunction with a comprehensive study of ventilatory function in healthy adult Nigerians (Femi-Pearse and Elebute, 1971). In order to determine the usefulness of the standard values of PFR obtained from studying healthy subjects, they have been compared with PFR in adult Nigerian asthmatics.

## MATERIALS AND METHODS

Anthropometric measurements, lung volumes, and PFR were obtained from 230 healthy Nigerian subjects living in Lagos, the capital and main port of Nigeria. There were 142 men and 88 women. The subjects were distributed uniformly between the age group 17 to 19 and five-year age groups from 20 to 54 in men and 20 to 44 in women. Older subjects were not readily available for study. All subjects appeared healthy, none had been exposed to dusty occupations, all were drawn from institutions which had efficient medi-care for their staff, and most were employees of the Nigerian Railway Corporation working as accounting and printing executives, clerks, and cooks. There were no engine drivers nor firemen among them. A few were medical students and hospital employees of Lagos University Teaching Hospital.

The following criteria were required for acceptance as a 'normal' subject:

(1) no history of cardiopulmonary disease;
(2) capacity to co-operate adequately during the tests;
(3) no evidence or history of disease which might affect pulmonary function.

These standards were similar to those set out by the

Veterans Administration—Army Co-operative study of pulmonary function (Kory, Callahan, Boren, and Syner, 1961), except that chest radiographs were not obtained at the time of the study. However, a normal chest film is a prerequisite of employment at both the Nigerian Railway Corporation and Lagos University Teaching Hospital.

Anthropometric measurements were obtained as follows:

Height without shoes, weight with minimal clothing, chest expansion, and abdominal circumference at the umbilicus at end-tidal expiration.

The Wright peak flow meter was used to measure PFR. Only one meter was employed for all the determinations, and it had been calibrated from the factory. Each subject had five determinants of PFR after being fully instructed about the details of the manoeuvre. The best determination was recorded at ambient temperature and pressure saturated with water vapour (ATPS). Vital capacity (VC), forced expiratory volume in one second ($FEV_1$), inspiratory capacity (IC), expiratory reserve volume (ERV), functional residual capacity (FRC), and total lung capacity (TLC) were also measured in each subject and recorded at body temperature and pressure saturated with water vapour (B.T.P.S.). The details of the methods employed to measure these lung volumes have already been described elsewhere (Femi-Pearse and Elebute, 1971). Statistical analysis of the data obtained was carried out with the help of an IBM 1620 computer. PFR was correlated with anthropometric measurements and lung volumes. Regression equations were then calculated for predicting PFR from anthropometric measurements and for predicting lung volumes from PFR. Using the Student's *t* test, the mean PFR of our subjects was compared with the mean of predicted values calculated from formulae which had been previously reported in the literature.

In the other part of the study, PFR was determined in 16 adult Nigerian asthmatics, nine men and seven women. The determinations were compared with predicted normal values calculated with the aid of regression equations which gave the lowest standard error of estimates in the study of healthy individuals, and with other ventilatory data obtained from the asthmatics.

## RESULTS

The mean values of PFR for the persons studied were 482·1 l/min (±83·3) for men and 385·6 l/min (±65·7) for women. The mean predicted values derived from the formulae based on age and height of Americans studied by Leiner *et al.* (1963) were 578·5±39·9 for men and 436·9±23·5 for women. For both men and women the observed values were significantly lower than the predicted values (P<0·0001). Table I presents a comparison of mean PFR of five-year age groups from 30 to 59 years among Londoners studied by Tinker (1961) and Nigerians. PFR is clearly lower among Nigerians than in the British.

### TABLE I

COMPARISON OF MEAN PFR (l/min) OF VARIOUS AGE GROUPS AMONG NIGERIAN AND BRITISH MEN

| Age Group | Nigerian (Present study) | British (Tinker, 1961) |
|---|---|---|
| 30–34 | 471 | 622 |
| 35–39 | 496 | 586 |
| 40–44 | 467 | 583 |
| 45–49 | 475 | 552 |
| 50–54 | 424 | 496 |
| 55–59 | 405 | 517 |

Tables II and III show the correlation of PFR with various anthropometric measurements and lung volumes in men and women, respectively. In both men and women there is a statistically significant negative correlation with age. In men, the correlation coefficients with height and weight

### TABLE II

CORRELATION OF PFR WITH PHYSICAL CHARACTERISTICS AND LUNG VOLUMES IN 142 NIGERIAN MEN

| | Mean | S.D. | Correlation Coefficient with PFR | P |
|---|---|---|---|---|
| Age yr) | 34·9 | 12·0 | −0·310 | <0·001 |
| Height (cm) | 168·1 | 6·6 | 0·329 | <0·001 |
| Weight (kg) | 65·7 | 10·0 | 0·181 | <0·05 |
| Chest expansion (mm) | 30·7 | 9·0 | 0·013 | N.S. |
| Chest circumference at expiration (cm) | 82·1 | 6·6 | 0·156 | N.S. |
| Abdominal circumference (cm) | 77·1 | 9·5 | −0·061 | N.S. |
| VC (ml) | 3354 | 600 | 0·475 | <0·001 |
| $FEV_1$ (ml) | 2704 | 699 | 0·494 | <0·001 |
| IC (ml) | 2096 | 557 | 0·305 | <0·001 |
| ERV (ml) | 1244 | 397 | 0·313 | <0·001< |
| FRC (ml) | 2074 | 693 | 0·208 | <0·05 |
| TLC (ml) | 4186 | 850 | 0·362 | <0·001 |

N.S. = Not statistically significant.

### TABLE III

CORRELATION OF PFR (l/min) WITH PHYSICAL CHARACTERISTICS AND LUNG VOLUMES IN 88 NIGERIAN WOMEN

| | Mean | S.D. | Correlation Coefficient with PFR | P |
|---|---|---|---|---|
| Age (yr) | 29·4 | 8·5 | −0·509 | <0·001 |
| Height (cm) | 161·1 | 6·9 | −0·051 | N.S. |
| Weight (kg) | 62·2 | 12·7 | −0·192 | N.S. |
| Chest expansion (mm) | 32·5 | 14·1 | 0·267 | <0·05 |
| Chest circumference at expiration (cm) | 81·2 | 7·9 | 0·020 | N.S. |
| Abdominal circumference (cm) | 76·6 | 11·9 | −0·353 | <0·001 |
| VC (ml) | 2547 | 525 | 0·614 | <0·001 |
| $FEV_1$ (ml) | 2004 | 484 | 0·595 | <0·001 |
| IC (ml) | 1618 | 459 | 0·437 | <0·001 |
| ERV (ml) | 922 | 309 | 0·372 | <0·001 |
| FRC (ml) | 1655 | 658 | 0·122 | N.S. |
| TLC (ml) | 3276 | 745 | 0·360 | <0·001 |

N.S. = Not statistically significant.

## TABLE IV

FORMULAE FOR PREDICTING PFR FROM AGE, HEIGHT, AND WEIGHT OF ADULT NIGERIANS

| Predictors Used | Sex | Coefficient for Age (yr) | Coefficient for Height (cm) | Coefficient for Weight (kg) | Constant | R[1] | S.E.E.[2] |
|---|---|---|---|---|---|---|---|
| Age | M | −2·19 | — | — | 557·8 | −0·310 | 81·0 |
| | F | −3·88 | — | — | 498·4 | −0·509 | 56·5 |
| Height | M | — | 4·23 | — | −229·7 | 0·329 | 80·5 |
| Weight | M | — | — | 1·53 | 380·9 | 0·181 | 83·8 |
| Age, Height | M | −1·73 | 3·47 | — | −41·5 | 0·406 | 78·2 |
| | F | −3·99 | −1·07 | — | 673·2 | −0·516 | 56·3 |
| Age, Weight | M | −2·51 | — | 2·08 | 43·2 | 0·393 | 78·6 |
| | F | −4·07 | — | 0·29 | 486·3 | −0·502 | 56·7 |
| Height, Weight | M | — | 4·10 | 0·18 | −218·6 | 0·330 | 80·8 |

[1] Correlation coefficient; where more than one independent variable is present, multiple correlation coefficient is given.
[2] Standard error of estimate.

are also significant, while in women there is a significant negative correlation with abdominal circumference. Table IV presents the regression formulae calculated for predicting PFR from age, height, and weight among adult Nigerians. The combination of age and height gave the formula with the lowest standard error of estimates.

In both men and women, PFR correlates significantly with all lung volumes with the exception of FRC in women. Tables V and VI present the correlation coefficients of PFR with lung volumes as well as the regression equations for predicting lung volumes from PFR.

Table VII shows the correlation of PFR with physical measurements and lung volumes in 16 adult Nigerian asthmatics. Although the number of patients was small, a significant correlation was obtained between PFR and VC, $FEV_1$, and ERV. In Table VIII, the patients are grouped according to the severity of their symptoms and on the basis of their $FEV_1$% ($FEV_1$/FVC%) and their forced vital capacity (FVC), the latter being expressed as a percentage of the predicted value. FVC of more than 90% of the predicted value and $FEV_1$% of more than 70 were taken as 'normal'. A diminished FVC was assumed to be an indication of a restrictive ventilatory defect while a lowered $FEV_1$% indicated an obstructive defect. PFR (expressed as a percentage of predicted values) was highest in those asthmatics who had no symptomatic or spirometric signs of any ventilatory defect, and lowest in those who had signs of both obstructive and restrictive defects.

## TABLE V

CORRELATION OF PFR (l/min) WITH LUNG VOLUMES AND REGRESSION EQUATIONS FOR PREDICTING LUNG VOLUMES FROM PFR IN NORMAL NIGERIAN MEN

| Lung Volume | Correlation Coefficient | Regression Coefficient | Regression Constant | S.E.E. |
|---|---|---|---|---|
| VC (ml) | 0·475[2] | 3·31 | 1774 | 531 |
| $FEV_1$ (ml) | 0·494[2] | 4·06 | 752 | 608 |
| IC | 0·305[2] | 1·96 | 1162 | 535 |
| ERV | 0·313[2] | 1·47 | 537 | 383 |
| FRC | 0·208[1] | 1·68 | 1262 | 692 |
| TLC | 0·362[2] | 3·64 | 2441 | 799 |

[1] Significant at the 0·05 level.
[2] Significant at the 0·001 level.

## TABLE VI

CORRELATION OF PFR (l/min) WITH LUNG VOLUMES AND REGRESSION EQUATIONS FOR PREDICTING LUNG VOLUMES FROM PFR IN NORMAL NIGERIAN WOMEN

| Lung Volume | Correlation Coefficient | Regression Coefficient | Regression Constant | S.E.E. |
|---|---|---|---|---|
| VC (ml) | 0·614[1] | 4·67 | 733 | 397 |
| $FEV_1$ (ml) | 0·595[1] | 3·86 | 506 | 349 |
| IC (ml) | 0·437[1] | 3·00 | 473 | 409 |
| ERV (ml) | 0·372[1] | 1·64 | 266 | 275 |
| FRC (ml) | 0·122 N.S. | — | — | — |
| TLC (ml.) | 0·360[1] | 4·23 | 1617 | 726 |

[1] Significant at 0·001 level.
N.S. = Not significant.

## TABLE VII

CORRELATION OF PFR (l/min) WITH PHYSICAL CHARACTERISTICS AND LUNG VOLUMES IN ADULT NIGERIAN ASTHMATICS

| | Mean | S.D. | Coefficient of Correlation with PFR | Significance of Correlation P |
|---|---|---|---|---|
| Age (yr) | 33·5 | 10·5 | −0·400 | N.S. |
| Height (cm) | 167·1 | 5·7 | 0·140 | N.S. |
| Weight (kg) | 59·6 | 8·5 | 0·117 | N.S. |
| VC (ml) | 2386 | 871 | 0·687 | < 0·001 |
| $FEV_1$ (ml) | 1041 | 455 | 0·823 | < 0·001 |
| ERV (ml) | 785 | 443 | 0·660 | < 0·01 |
| FRC (ml) | 2433 | 1001 | 0·170 | N.S. |
| TLC (ml) | 4035 | 1251 | 0·381 | N.S. |

N.S. = Not significant.

TABLE VIII

COMPARISON OF PFR WITH OTHER VENTILATORY DATA IN ADULT NIGERIAN ASTHMATICS

| No. of Patients | Wheeze | FVC % Predicted | $\frac{FEV_1}{FVC}$ % | Type of Pulmonary Disease | PFR % Predicted |
|---|---|---|---|---|---|
| 2 | Absent | 107·0[1] | 71·0 | — | 93·6 |
| 2 | Present | 72·3 | 71·0 | Restrictive | 72·1 |
| 2 | Present | 109·8 | 33·5 | Obstructive | 57·2 |
| 7 | Present | 73·1 | 50·6 | Obstructive and restrictive | 34·3 |
| 3 | Audible to unaided ears | 50·9 | 46·7 | Obstructive and restrictive | 29·3 |

[1] Figures represent average values.

## DISCUSSION

The results presented in this study show that peak flow rate, determined with Wright's peak flow meter, is lower in Nigerians than in either Americans or the British. This is in agreement with the lower values of VC, $FEV_1$, and TLC which have been found in Nigerians as well as in other peoples of African descent (Abramowitz, Leiner, Lewis, and Small, 1965; Johannsen and Erasmus, 1968; Femi-Pearse and Elebute, 1971). No satisfactory explanation has been offered for racial variations of lung volumes. It is unlikely that these differences can be accounted for by a high prevalence of childhood respiratory infections as suggested by Glass (1962) in his comparison of Maoris with Caucasian New Zealanders. It is likely, however, that there are racial differences in thoracic cage size or shape. The racial differences in ventilatory capacity necessitate the calculation of different standard values for the various races. Tables of standard values of PFR and other lung volumes have been prepared for Nigerians and are being published elsewhere (Elebute and Femi-Pearse, 1971). The similarity of values obtained for lung volumes among Nigerians with those obtained in South African Bantus by Johannsen and Erasmus (1968) makes it likely that the tables prepared from data collected in Nigeria may be applicable to other Africans.

There is a positive correlation between PFR and VC or $FEV_1$. This correlation has been reported previously by several authors and is known to occur both in healthy individuals and in patients who have ventilatory defects (Prime, 1960; Ritchie, 1962; Fairburn, Fletcher, Tinker, and Wood, 1962; Leiner *et al.*, 1963). PFR can, therefore, be used in the assessment of patients with pulmonary disease. The values of PFR obtained in the presence of various types of ventilatory defect differ, but there is too much overlap to permit a clear differentiation between restrictive and obstructive ventilatory defects. The lowest values of PFR are to be expected in the severer forms of respiratory disease in which there is a combination of obstruction and restriction of ventilation.

The simplicity of the peak flow test makes it particularly suitable for epidemiological studies of respiratory diseases (Ferris and Anderson, 1964; Toyama, 1964). Although some objection has been raised to the intrinsic validity of the peak flow test (Macklem and Mead, 1967), it is clear that in a population study this test will identify persons with gross ventilatory defects. Many inaccurate statements are made about the incidence in Africa of such diseases as asthma, chronic bronchitis, and emphysema. Population surveys of ventilatory function are, therefore, required in Africa; and the peak flow meter is conveniently portable and likely to be the most suitable instrument for such surveys.

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