VENTILATORY FUNCTION IN HEALTHY ADULT NIGERIANS

D. FEMI-PEARSE* AND E. A. ELEBUTE

Cardiothoracic Research Laboratory, Lagos University Teaching Hospital,
Lagos

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SUMMARY

1. Static and dynamic lung volumes (VC, FEV₁, FRC, ERV, RV and TLC) have been determined in 291 adult healthy Nigerians (174 males and 117 females).

2. Prediction formulae of various authors on Caucasians and South African Bantu have been applied to the Nigerian data. The results show significantly smaller VC, FEV₁, FRC, RV, TLC and RV/TLC in Nigerians than in Caucasians. The VC, FEV₁, and FRC of Nigerians were similar to those of South African Bantu.

3. ERV values were similar to those previously reported by other authors for Caucasians. The combination of lower RV values and similar ERV indicates the possibility of less 'basal airway closure' in Nigerians.

Several investigators have shown the lung volumes of Africans and peoples of African descent to be significantly less than the values for Caucasians when standardized for age and height (Smillie & Augustine, 1926; Roberts & Crabtree, 1927; Gilson, Stott, Hopwood, Roach, McKerrow & Schilling, 1962; Abramowitz, Leiner, Lewis & Small, 1965; Johannsen & Erasmus, 1968; Hearn, 1968; Oduntan, 1970). Other racial groups also shown to have lower lung volumes compared with Caucasians include Chinese (Foster, 1924), Indians (Rao, Gupta Sen, Saha & Devi Sita, 1961; Cotes & Malhotra, 1965; Bhattacharya & Banerjee, 1966) and Maoris (Glass, 1962).

These findings support the need for each racial or ethnic group to have its own 'normal' standards of pulmonary function. The aim of the present study was to establish 'normal' values for ventilatory functions in Nigerians. A sample of 291 healthy Nigerian adults were studied. All the sub-divisions of total lung capacity were compared with values predicted by formulae previously derived by other authors for Caucasians and for South African Bantu.

Whereas the lung volumes of Nigerians are very similar to those of South African Bantu, the present study confirms the differences previously reported by other workers between the lung

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Correspondence: Dr D. Femi-Pearse, Cardiothoracic Research Laboratory, Lagos University Teaching Hospital, Private Mail Bag 12003, Lagos, Nigeria.
volumes of Caucasians and those of Africans and persons of African descent. Most previously reported studies of ventilatory capacity in people of African descent have not included all the sub-divisions of total lung capacity. The measurement of all sub-divisions of total lung capacity in the present study revealed that there were important similarities between Caucasians and our Nigerian subjects in some lung volumes, whereas there were definite dissimilarities in other lung volumes.

MATERIALS AND METHODS

The group of 291 adult Nigerians that were studied, included 174 males and 117 females. Most of the subjects were Yorubas (244; 133 males and 91 females) and the rest were distributed among other Nigerian ethnic groups. Subjects were accepted for the study in such a way as to ensure an even distribution in the 17–19 years age-group and each quinquenium from 20 to 59 in males and 20 to 49 in females. There was difficulty in obtaining subjects in the older age-groups. Most of the subjects were employees of the Nigerian Railway Corporation (N.R.C.) working as accounting and printing executives. There were no engine drivers, firemen or foundry workers among the group. The remainder were medical students, nurses and workers of the Lagos University Teaching Hospital (L.U.T.H.).

The following criteria were fulfilled for acceptance as ‘normal’ subjects. (a) No history of disease of the heart or lung. (b) Capacity to co-operate adequately during the tests. (c) No evidence or history of any disease which could be expected to alter pulmonary function.

Chest X-rays were not obtained at the time of the study. However, all members of staff of N.R.C. and L.U.T.H. must have normal chest X-rays as a condition of employment.

The anthropometric and ventilatory data collected on each subject included age (years), weight (kg), height (cm), vital capacity (VC, ml), forced expiratory volume in 1 s (FEV₁, ml), forced expiratory volume as percentage of VC (FEV₁%, %), inspiratory capacity (IC, ml), expiratory reserve volume (ERV, ml), functional residual capacity (FRC, ml), residual volume (RV, ml), total lung capacity (TLC, ml) and RV/TLC ratio (%).

Weight and height were measured in light clothing, but without shoes. A 6-litre spirometer (C. F. Palmer Recording Spirometer, C. F. Palmer, London) was used for the ventilatory measurements. All measurements were made with subjects in a sitting position. Each subject practised the manoeuvres for the determination of lung volumes twice and only those who succeeded during practice were allowed to proceed with the tests. The better of two manoeuvres each for ERV, VC and FVC was recorded in this study. No subject had a VC greater than the capacity of the spirometer. All lung volumes were corrected to body temperature and pressure, saturated with water vapour at body temperature (BTPS). For calibration the two speeds of the kymograph used in this study were checked against a stop-clock by making three sets each of 10s runs on continuous rolls of paper. The distance run in each 10s agreed with the speed of the kymograph. The spirometer was also checked by water displacement over several litres and volumes recorded on the kymograph were identical with the volumes of water displaced. The vital capacity readings on the spirometer corresponded closely to the FVC measured on the vitalograph (Vitalograph Clinical Outfit, Vitalograph Limited, Buckingham, England). FEV₁ was recorded by the vitalograph. FRC was determined by the multiple breath helium dilution method of Meneely & Kaltreider (1949). The helium cathrometer was calibrated over a range of 0–15% of helium by adding measured amounts of 100% helium.
from the cylinder to the measured volumes of air in the spirometer circuit. Calibration in this way gave values that were within plus or minus 5% of the exact amount. Variability of our FRC results was tested by daily measurement of FRC by the helium dilution method in four subjects for four consecutive days. All the FRC results were within 100 ml in each of the subjects. An electronic data-processing machine (IBM 1620) was used to develop a product-moment correlation matrix of all the variables measured. Regression equations based on age, height and weight were calculated for VC, FEV1, ERV, FRC and TLC. This was done in a stepwise manner, and the final equation chosen was that which gave the lowest standard error of estimates.

The mean lung volumes of Nigerian females as percentages of the mean male values were determined. Also, prediction formulae for Nigerian males were applied to the female data, to highlight sex differences. Predicted values so obtained were compared statistically with observed values by student's t-test.

Smoking habits of all subjects were analysed and the lung volumes of smokers were compared statistically with those of non-smokers by using student's t-test.

Also, the data from 291 Nigerians were subjected to the regression formulae derived for Caucasians by Baldwin, Courand & Richards (1948), Needham, Rogan & McDonald (1954) and Kory, Callahan, Boren & Syner (1961) and those derived for South African Bantu by Johannsen & Erasmus (1968). Statistical comparisons, using student's t-test, were made between our observed values and the values predicted by the various formulae.

The terms, symbols and definitions for the divisions of the lung volume and for ventilatory measurements are those of Pappenheimer, Comroe, Courand, Ferguson, Filley, Fowler, Gray, Helmholz, Otis, Rahn & Riley (1950).

RESULTS

The mean values for each of the variables measured are presented in Table 1. Each of the variables measured was correlated with the others (Tables 2 and 3) deposited as Clinical Science Tables 41/1 and 41/2 with the Librarian at the Royal Society of Medicine). There was inverse correlation between age and the lung volumes. For example, correlation coefficients (r) between age and VC in males and females were -0.455 (P<0.001) and -0.301 (P<0.001) respectively. Height correlated at a high level of significance with the lung volumes in males (e.g. with VC, r = 0.519; P<0.001). In females height showed no significant correlation with VC, whereas the correlation reached low levels of significance with other lung volumes (ERV, r = 0.192; FRC, r = 0.208; TLC, r = 0.226; P<0.05). Weight correlated inversely with ERV, r = -0.209 (P<0.05) in females but not in males.

Regression coefficients and constants for the prediction of VC, FEV1, ERV, FRC and TLC from age, height and weight are presented in Table 4 (deposited as Clinical Science Table 41/3 with the Librarian at the Royal Society of Medicine).

The observed VC values in Nigerians are compared with the predicted values for Caucasians and South African Bantu in Figs. 1 and 2. It is clear that in all 5 year age groups, the Nigerian values are significantly less than the predicted values derived from formulae for Caucasians (P<0.001), whereas they are not significantly different in most age groups from predicted values derived from the formulae for South African Bantu.

Figs. 1 and 2 also show the observed and predicted values of FRC, RV, ERV, TLC and
### TABLE 1. Mean and standard deviations of variables based on 174 male and 117 female Nigerians

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Male subjects</th>
<th>Female subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>34·5</td>
<td>11·6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65·8</td>
<td>9·4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168·2</td>
<td>6·2</td>
</tr>
<tr>
<td>VC (ml)</td>
<td>3410</td>
<td>621</td>
</tr>
<tr>
<td>FEV₁ (ml)</td>
<td>2701</td>
<td>705</td>
</tr>
<tr>
<td>FEV₁ %</td>
<td>79·3</td>
<td>13·6</td>
</tr>
<tr>
<td>IC (ml)</td>
<td>2143</td>
<td>563</td>
</tr>
<tr>
<td>ERV (ml)</td>
<td>1249</td>
<td>390</td>
</tr>
<tr>
<td>FRC (ml)</td>
<td>2112</td>
<td>738</td>
</tr>
<tr>
<td>RV (ml)</td>
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<td>642</td>
</tr>
<tr>
<td>TLC (ml)</td>
<td>4271</td>
<td>896</td>
</tr>
<tr>
<td>RV/TLC (%)</td>
<td>18·6</td>
<td>11·4</td>
</tr>
</tbody>
</table>

**FIG. 1.** Observed lung volumes in Nigerian males compared with the predicted values derived from formulae for Caucasians and South African Bantu. ●, Needham et al. (1954); △, Kory et al. (1961); ■, Baldwin et al. (1948); ○, this study; □, Johannsen & Erasmus (1968).
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RV/TLC. In almost all age groups of both sexes the FRC, RV, TLC and RV/TLC are significantly less in Nigerians than in Caucasians ($P < 0.001$). The absence of significant differences among females in the 45–49 year age group is probably due to the small number of subjects.

One outstanding result is the closeness of the observed ERV in Nigerians to that predicted from the formulae derived for Caucasians by Needham et al. (1954). Among our females there is no statistically significant difference between the observed and the predicted values in any of the seven age groups. Although the differences in four out of nine age groups of males are statistically significant, they are less than 25% of the predicted values.

The mean values obtained in our study and the mean predicted by the formulae of Needham et al. (1954) and Johannsen & Erasmus (1968) have been expressed diagramatically in Figs. 3 and 4. These figures compare the spirometric representations of the lungs as seen in our Nigerian subjects with Caucasians and Bantu. It is clearly evident that apart from the tidal volumes which have been assumed to be the same in the three groups, only the ERV is comparable in the Nigerian with the Caucasian. Whereas there is no statistically significant difference in the FRC between Nigerians and Bantu, the RV is significantly smaller in Nigerians.

There are statistically significant differences between lung volumes in females and males.
When the VC, ERV, FRC, RV and TLC of our female subjects are expressed as percentages of the male data, the results are 75, 74, 78, 86 and 77%, respectively. The differences between the observed values for females and the predicted reach high levels of statistical significance.

**Fig. 3.** Diagrams of spirometric representation of the lungs in males: Nigerian (A), Caucasian (B) and South African Bantu (C).

**Fig. 4.** Diagrams of the spirometric representation of the lungs in females: Nigerian (A), Caucasian (B) and South African Bantu (C).

Forty males were classified as mild smokers (one to ten cigarettes daily), and six each were moderate and severe smokers (eleven to twenty and over twenty cigarettes daily respectively).
Only six females were mild smokers. The lung volumes in smokers were less than in non-smokers, but the differences did not reach significant levels. Whereas smokers had a 5% diminution in vital capacity, their RV/TLC ratio was 11.5% higher than in non-smokers.

**DISCUSSION**

The Nigerian subjects in this study do not form a representative sample of the population and the results obtained would refer particularly to the Yoruba ethnic group. Several factors, such as the size of the sample and the evenness of age distribution, diminish the chance occurrence of errors. The coefficients of variation in this study compare very favourably with those previously reported by other authors. For example, the coefficient of variation for VC in our males is 18.2% as compared with 18% for males studied by Needham et al. (1954) and 15.9% by Johannsen & Erasmus (1968). The corresponding values for females are 20.6, 20.0 and 14.9% respectively.

It is of great interest that our FRC values measured by the helium dilution method are very close to those of Johannsen & Erasmus (1968), who employed the open circuit method of Darling, Cournard & Richards (1940) in their study of Bantu subjects. The mean FRC for our males is 2112 ml as compared with 2220 ml for South African Bantu, whereas the corresponding values for females are 1655 ml and 1644 ml respectively. After allowing for the fact that the values of Johannsen & Erasmus (1968) were recorded at ATPS, the difference between our values and theirs is still less than 10%.

The mean values of TLC and all its subdivisions are greater in males than in females. However, the ratios as a percentage of TLC are similar in both sexes, which means that the ventilatory patterns are similar (e.g. VC/TLC 80% in males and 79% in females).

It has been shown in this study that anthropometric features such as height and weight cannot explain the difference between males and females. When female data are subjected to the prediction formulae for males, there are significant differences between observed and predicted values of VC, ERV, FRC and TLC ($P < 0.001$). In other words, females of similar age, height and weight do not share identical lung volumes with males. It follows that other factors such as difference in muscular strength, size and shape of thoracic cage and elasticity of the lung must be considered.

This study confirms again the significantly lower lung volumes (VC, FRC, RV, TLC) of peoples of African descent compared with Caucasians (Smillie & Augustine, 1926; Roberts & Crabtree, 1927; Gilson et al., 1962; Abramowitz et al., 1965; Johannsen & Erasmus, 1968; Hearn, 1968). Normal values for people of African descent may vary over a wide range. For example, our values for VC in Nigerian males are smaller than those reported by Hearn (1968) for Negro workers in Trinidad, but are similar to the values obtained in South African Bantu.

The operative factors for the lower VC, FRC, RV and TLC in Africans and other races compared with Caucasians may be the same as those which produce differences in lung volumes between males and females within any race. It would therefore seem justifiable in the future to examine in particular the relative capacities and shapes of the thoracic cage, respiratory muscle strength and elastic recoil of the lungs in the various races.

Our findings differ from those of Johannsen & Erasmus (1968) on South African Bantu with regard to RV/TLC ratios. Our ratios for all male and female subjects are significantly smaller than the values predicted by the formulae of Needham et al. (1954) and Johannsen & Erasmus.
In our study the FRC/TLC and RV/TLC ratios remained low even in the older age groups, whereas in white and Bantu subjects the ratios increase steadily with advancing age. Normal values for people of European descent may also vary over a wide range (Figs. 1 and 2). The failure of RV and FRC in Nigerians to rise with age may reflect the variability of lung volumes within any race. This observation may be due to environmental factors.

Studies in the U.S.A. have shown that Negroes develop chronic bronchitis and emphysema, but with lesser frequency than Caucasians (Murphy, Katz, Massaro & Luchsinger, 1962; Massaro, Cusick & Katz, 1965). However, post mortem study of the lungs of native Jamaicans (who are mostly of Negro ancestry) has shown little difference in frequency and severity of pan-acinar emphysema between Negro, Chinese, East Indian and Caucasians (Hayes & Summerell, 1969; Hayes, 1970). Also, Walshe & Hayes (1967) have shown that chronic respiratory symptoms are more commonly found in smokers than in non-smokers in the indigenous hospitalized Jamaican. The more common occurrence of chronic bronchitis and emphysema in Caucasians than in Negroes in the U.S.A. is probably a reflection of the greater number of cigarettes smoked by the former (Haenszel, Shimkin & Miller, 1956). Factors which provoke alveolar and airway degeneration such as cigarette smoking and atmospheric pollution are of minimal significance in the Nigerian community at the present time. In fact, only six of 174 males smoked more than twenty cigarettes daily, and only six females smoked, all less than ten cigarettes daily.

During expiration towards residual volume, the lower lung zones empty more rapidly than the upper zones (Milic-Emili, Henderson, Dolvich, Trop & Kaneko, 1966), and regional elastic recoil falls more rapidly. This factor together with gravity leads to closure of the basal airway at lung volumes below FRC. This 'basal airway closure' is increased in older people and in cigarette smokers (Holland, Milic-Emili, Macklem & Bates, 1968; Jones & Clarke, 1969; Leblanc, Ruff & Milic-Emili, 1970). The similar ERV values coupled with the lower RV and FRC and the failure of the latter volumes to rise with age in our subjects as compared with Caucasians indicate a need to investigate 'basal airway closure' in Nigerians.

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REFERENCES


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