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Lung volumes in normal Cantonese subjects: preliminary studies

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Ching, B. and Horsfall, P. A. L. (1977). *Thorax*, **32**, 352–355. **Lung volumes in normal Cantonese subjects: preliminary studies.** Measurements of forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, functional residual capacity (FRC), total lung capacity (TLC), residual volume (RV), and RV/TLC ratio have been made in 331 normal Cantonese subjects (134 male and 197 female). The results have been expressed in multiple regression equations relating the volumes to age, height, and weight and have been compared with those of other workers. Lung volumes obtained in this study are in general lower for Chinese subjects than those reported for Caucasians. Similar findings for FVC were reported by Chuan and Chia (1969) in Singapore and by Wu and Yang (1962) in Taiwan. Significant differences, however, are noted for FRC, TLC, RV, and RV/TLC between our findings and those of Chuan and Chia. Our series is unbalanced because of an uneven distribution of age groups. In fact in none of the reported studies on Chinese subjects, including that of da Costa (1971), is the series large or balanced. Clearly, further research is required in this ethnic group to get more reliable predictive formulae for lung volumes.

In clinical practice, lung function is usually assessed by simple measurement of lung volumes and ventilation. Predicted, that is, 'normal', values are calculated from formulae derived from studies of healthy populations. There is evidence of ethnic differences, average values for Chinese subjects being below those for Caucasians. The present study was designed to explore further these reported ethnic differences in lung volumes.

Material and methods

A total of 331 Cantonese subjects, ranging in age from 17 to 56 years, were studied. There were 134 male and 197 female subjects in the group. Most of the men were hospital employees who performed manual work but a number of young men, ranging in age from 18 to 25 years, were trainees from the Police Training College. The 197 women were nurses or manual workers in the hospital, and, of the total, 124 were young student nurses ranging in age from 17 to 25 years. All the subjects had normal chest radiographs within the six-month period before the testing and all were clinically free from chest diseases or any other disorders that could affect the results.

A smoking history was obtained in all of the male subjects, 70 of whom were non-smokers (52%) while 64 (48%) smoked. The smokers were divided into three groups: smoked fewer than 10 cigarettes per day—light smokers; smoked 10 to 20 cigarettes per day—moderate smokers; and smoked more than 20 cigarettes per day—heavy smokers. Among the female subjects a smoking history was obtained in only a few subjects.

Measurements of ventilatory capacity were made on the Pulmonet 114 apparatus which has a 9-litre spirometer bell of light weight. All subjects cooperated well in the tests which were performed with the subjects sitting after rest but not at basal condition. Height was recorded in inches without shoes, weight was measured in pounds with indoor clothes, and age was recorded in years to the last birthday. Ranges, mean values, and standard deviations for the age, height, and weight of the subjects studied are shown in Table 1.

The functional residual capacity (FRC) was measured using the closed-circuit helium dilution method (Meneely and Kaltreider, 1949) followed by the ordinary volumetric method (Herrald and McMichael, 1939).

Immediately after the determination of FRC, a

Table 1 *Range, mean values, and standard deviations for age, height, and weight of subjects*

Measurement	*Females (197)*			*Males (134)*		
	Range	*Mean*	*SD*	*Range*	*Mean*	*SD*
Age (years)	17–56	28·1	10·453	18–56	29·9	11·588
Height (in)	56–69	61·2	2·074	56–70	65·2	2·549
Weight (lb)	84–156	109·0	15·024	97–168	124·8	13·089

short tracing of the resting tidal volume was recorded at a slow kymograph speed (1 mm/s). The forced vital capacity (FVC) was measured by instructing the subjects to breathe in as deeply as possible and then to exhale as hard and fast as possible into the spirometer. The inspiratory capacity (IC) and expiratory reserve volume (ERV) were measured. Forced expiratory volume in one second (FEV_1) and FEV were measured in triplicate with a fast drum speed of 20 mm/s. The residual volume (RV) and the total lung capacity (TLC) were calculated by subtracting ERV from FRC and adding the FVC to the RV respectively.

All gas volumes were then corrected to body temperature and pressure, saturated with water vapour (BTPS) (Comroe and Kraffert, 1950).

The linearity of the helium meter had been confirmed by serial dilution. Biological calibration for assessing the reliability of results on Pulmonet type 114 had also been done.

Statistical analysis

Each independent variable (age, height, and weight) was used initially for deriving correlation coefficients (r) for the seven lung compartments. Each of these correlation coefficients was then analysed to determine if its effect was statistically significant at the 5% and 1% levels (Geigy tables). Regression equations for each lung compartment were then worked out on each variable singly, on every pair of variables, and on each triplet of variables respectively. The abbreviated Doolittle method was used for multiple regression equations, derived from three independent variables. The inverse matrix was used for construction of confidence intervals as a check on the regression coefficients.

The 13 best regression equations are shown in Tables 2 and 3.

The regression equations derived reflect the negative effect of increasing age and the positive effect of increasing height on FVC and FEV_1 in both male and female subjects. FEV_1/FVC ratio is independent of age; FRC, RV, and RV/TLC in females reflect the positive effect of increasing age and height, but the inclusion of weight in the formulae does increase the predictive value to a significant degree, weight exerting a negative effect. TLC is independent of age in both sexes. In the male group, age did not have any significant correlation with FRC, nor were we able to derive an equation for RV. RV/TLC ratio was affected by age only. The inclusion of weight in the formulae for males does not increase the predictive value.

Discussion

Because the only populations available and suitable for study were hospital workers and police trainees, the series is unbalanced in that the numbers in the older age groups are inadequate, thus diminishing the effect of age in the final equation. In the male group, the height in the young (20 to 30 years) age group showed a standard deviation of only 1·4 inches. Here again the effect of the

Table 2 *Best regression equation for predicted values of lung volume and its subdivisions in 197 female subjects*

Measurement	*Regression coefficient*			*Constant*	*r*	*SEE*
	Age (yr)	*Height (in)*	*Weight (lb)*			
FVC (litres)	−0·010±0·002 t=4·152	0·082±0·012 t=7·057		−1·993±0·775	±0·556	±0·327
FEV_1 (litres)	−0·021±0·002 t=9·417	0·065±0·011 t=5·914		−1·062±0·733	±0·673	±0·309
FEV_1/FVC×100	0·476±0·046 t=10·393			98·130±1·287	±0·597	±6·704
FRC (litres)	0·006±0·002 t=2·527	0·096±0·012 t=7·705	−0·010±0·002 t=5·671	2·948±1·021	±0·510	±0·320
TLC (litres)		0·128±0·014 t=8·934		−4·157±0·875	±0·539	±0·415
RV (litres)	0·010±0·002 t=5·678	0·057±0·009 t=6·490	−0·005±0·001 t=4·082	−2·307±0·719	±0·472	±0·225
RV/TLC×100	0·292±0·036 t=8·100	0·743±0·185 t=4·006	−0·142±0·026 t=5·520	−13·318±1·835	±0·524	±4·750

Table 3 *Best regression equation for predicted values of lung volume and its subdivisions in 134 male subjects*

Measurement	*Regression coefficient*			*Constant*	*r*	*SEE*
	Age (yr)	*Height (in)*	*Weight (lb)*			
FVC (litres)	−0·025±0·004 t=6·464	0·053±0·018 t=3·040		1·125±1·259	±0·651	±0·443
FEV_1 (litres)	−0·035±0·004 t=9·835	0·046±0·016 t=2·852		1·285±1·146	±0·761	±0·403
FEV_1/FVC×100	−0·377±0·045 t=8·426			94·596±1·339	±0·591	±5·981
FRC (litres)		0·063±0·015 t=4·379		−1·161±0·946	±0·356	±0·426
TLC (litres)		0·120±0·019 t=6·315		−2·677±1·240	±0·482	±0·559
RV/TLC×100	0·215±0·033 t=6·578			18·889±0·979	±0·497	±4·372

predictive value of height in the final equations in males may be diminished. The failure to find a significant correlation between RV and age in males, which would be expected, may well be accounted for by the preponderance of young subjects in the group studied.

In designing future studies we have calculated that in each age group 20 subjects would be desirable. The inclusion of smokers in a normal group may also be questioned. However, analyses of our results in smokers versus non-smokers failed to show any statistically significant effect of even heavy cigarette smoking on the lung volumes.

Comparisons of values for lung volumes calculated from our formulae have been made with values calculated for standard men and women using equations derived from other ethnic groups. Predicted values for Caucasians for FEV_1, FVC, and TLC are significantly higher than those predicted for our Chinese subjects (Needham *et al.*, 1954; Goldman and Becklake, 1959; Berglund *et al.*, 1963; Ferris *et al.*, 1965). Values for FVC and FEV_1 predicted by Johannsen and Erasmus (1968) for African males and females are significantly smaller than those from our subjects as are the values of Miller *et al.* (1970) for African males. However, values from Cookson *et al.* (1976) for FVC and FEV_1 in Rhodesian Africans are higher than those in our subjects, significantly so except for FEV_1 in females.

Comparing predicted values for standard men and women from our study with those reported in other Chinese groups, results for FVC are similar to those reported by Wu and Yang (1962) in Taiwan and by Chuan and Chia (1969) in Singapore; da Costa's (1971) formulae for Singapore Chinese predicted lower values for FEV_1 in males but similar values in females. For other parameters our values are significantly smaller for FRC, TLC, RV, and RV/TLC ratio in females and RV and RV/TLC ratio in males than those predicted by Chuan and Chia (1969). da Costa (1971) also predicts significantly higher figures for FRC, TLC, and RV than do our equations.

As Cookson *et al.* (1976) point out, however, the method of comparing standard men and women may not present a true comparison. We have therefore constructed regression lines for male and female subjects aged 40 for FVC and FEV_1 plotted against height and compared these against regression lines derived from the data of other authors. In the female subjects the lines for FEV_1 and FVC parallel those of Needham *et al.* (1954), Goldman and Becklake (1959), Berglund *et al.* (1963), Ferris *et al.* (1965), Johannsen and Erasmus (1968), Chuan and Chia (1969), Miller *et al.* (1970), da Costa (1971), and Cookson *et al.* (1976) for both FEV_1 and FVC, indicating similar regression rates. In male subjects the regression line for FEV_1 and FVC against height, derived for our subjects, shows a significantly smaller rate of regression for both FEV_1 and FVC than the regression lines derived from the other workers cited above. This may be accounted for by subject selection in that a percentage of our male subjects were police recruits selected for physical fitness, emphasising again the difficulty of finding a 'normal' population.

Reviewing the published results on assessment of lung function in normal Chinese subjects, it is clear that none of the series, including that of da Costa (1971), is large or balanced and that further measurements are required to obtain more reliable predictive formulae in this ethnic group.

While standing height is the most reliable indicator of lung size within an ethnic group (Kory *et al.*, 1961; Ferris *et al.*, 1965; Boren *et al.*, 1966; Cotes, 1968), other anthropometric measurements must be used to determine which factors account for the observed ethnic differences in lung capacities. It is known, for instance, that the ratio of stem to standing height is different in Africans and Caucasians, but van der Wal *et al.* (1971) showed that this difference did not account for all of the observed differences in vital capacity. Clearly, therefore, other detailed anthropometric measurements will have to be made and analysed before any conclusion can be reached on which factors determine the differences in lung volumes noted between ethnic groups. Serial studies will also be required to confirm that the operative factors are genetic and not environmental.

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