Thorax, 1978, **33**, 243–249

Pulmonary function studies in healthy Pakistani adults[1]

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Williams, D. E., Drew Miller, R., and Taylor, W. F. (1978). *Thorax*, **33**, 243–249. **Pulmonary function studies in healthy Pakistani adults.** Predicted normal spirometric values have been shown to have significant geographical and ethnic variation. These variations are of epidemiological significance in determining the prevalence of disease and of clinical importance in measuring the effects on pulmonary function of various diseases.

A total of 599 men were chosen from employees of a package manufacturer, a general hospital in Lahore, and a village in northern Pakistan; 94 students and staff of a women's college in Lahore were also studied.

The forced vital capacity (FVC) was recorded from three satisfactory efforts, and the FVC, one second forced expiratory volume (FEV_1), and maximal midexpiratory flow (MMF, or $FEF_{25-75\%}$) were calculated from the best FVC effort. The FVC and FEV_1 in men were found to be similar to those of a group of emigrant Pakistanis and a north-western Indian population (Delhi) but higher than populations in south and eastern India. Pakistani women had values similar to those of women in northern India.

None of the women smoked and, among Pakistani men, the smokers (285) averaged 6·7 pack years. While the FVC and FEV_1 values did not differ between smokers and non-smokers, there was a significant difference in MMF ($FEF_{25-75\%}$) in the two groups. This latter finding corroborates studies on North American populations in which smokers generally have had a higher lifelong cigarette consumption. This confirms the MMF ($FEF_{25-75\%}$) to be a more sensitive test of subtle, asymptomatic changes in pulmonary function than the more widely used FVC and FEV_1.

An increasing number of pulmonary function studies have demonstrated a significant variation in lung volumes among subjects of different racial or ethnic origin. It is generally accepted that of the various physical measurements the body height (or arm span if height is unavailable) (Hepper *et al.*, 1965) correlates best with lung volumes. Other anthropomorphic measurements, for example, weight, body surface area, chest circumference, and anteroposterior diameter of chest, are much less useful for deriving prediction equations for normal lung volumes. Many of the earlier surveys carefully evaluated these measurements but did not consider the subject's race or ethnic background (Barnhard *et al.*, 1960; Hepper *et al.*, 1960; Kory *et al.*, 1961; Ferris *et al.*, 1965; Boren *et al.*, 1966).

Abramowitz and others (1965) found forced vital capacity per centimetre of height to be significantly higher in 60 white men than in 51 black men. They concluded that different regression equations should be applied for white and black men. Other workers have found significant differences in white versus black populations in the United States (Damon, 1966; Densen *et al.*, 1969; Lapp *et al.*, 1974).

An increasing number of studies reported in the international literature attest to different regression curves or normal (prediction) values between white, or presumably white, subjects and Chinese subjects (Wu and Yang, 1962); Bhutanese (Cotes and Ward, 1966); Malaysian Aboriginals (Dugdale *et al.*, 1971); New Guineans (Woolcock

[1] This investigation was supported by a grant agreement of Pakistan and the United States using US Department of Health, Education, and Welfare PL 480 Funds. Grant number 19-P-58250-F-01.

et al., 1972; Cotes *et al.*, 1973); Bantu (Johannsen and Erasmus, 1968); Caribbeans (Miller *et al.*, 1972); and Indians (Cotes and Malhotra, 1965).

Rao *et al.* (1961) reported significantly lower static lung volumes in north-eastern Indians (Calcutta) than those previously reported in Europeans and white Americans. Raghavan and Nagendra (1965) studied 215 healthy Indian adults aged 17–33 in Bombay, India. They developed prediction formulae for vital capacity and maximum breathing capacity (MBC) based on height and weight. They reported measurements of VC and MBC at variance with several previous Indian workers. Their values for residual volume were similar to those of 'western workers' but total lung capacity was significantly lower in their subjects compared to 'western workers'. Jain and Ramiah (1969), studying pulmonary function in 188 healthy northern Indian (Delhi) men aged 15–40 years, found values closer to those reported in western studies.

It would seem from the studies mentioned above that normal values for a particular population must be derived specifically from a sampling of that population. The purpose of the study reported here was to analyse data obtained from healthy Pakistani subjects and to establish specific normal values. The study was part of an investigation of tuberculosis and other chest diseases in Pakistan with particular emphasis on medical and surgical therapy.

Methods

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and maximal mid-expiratory flow (MMF) or forced expiratory flow from 25 to 75% of the vital capacity ($FEV_{25-75\%}$) were measured in 599 Pakistani males who qualified for inclusion in this study. The same pulmonary function tests were measured in 94 Pakistani female subjects. The male subjects were employees at a factory which produces cardboard cartons and soft plastic containers, employees of United Christian Hospital, employees at the United States Agency for International Development (AID) in Lahore, and farmers in a village 160 miles south of Lahore. Female subjects included staff and students from Kinnaird College in Lahore.

Height and arm span were measured in inches to the nearest 0·25 inch with the subject standing barefoot with his back flat against a wall and arms outstretched. Spinal and lower extremity deformities from diseases such as poliomyelitis and tuberculosis are common enough in Pakistan to make height an unreliable measurement in some subjects. The observation by Hepper *et al.* (1965) that arm span may serve as a reliable alternative to height prompted us to include this measurement.

Tabulations of spirographic data on those subjects whose 70 mm chest radiograph was abnormal or technically unsatisfactory or who produced unsatisfactory FVC efforts were not included. Subjects were screened with a smoking and respiratory questionnaire and a miniature chest radiograph to exclude evidence of chest disease. The subjects were asked if they had suffered from tuberculosis or recent pneumonia, daily cough, purulent sputum, exertional dyspnoea, or palpitation. An affirmative answer to any of these six points and/or an abnormal chest film excluded subjects from the study.

A Jones Pulmonor Spirometer was used for measuring FVC and calculating the FEV_1 and MMF. At least three acceptable tracings were made by each subject in a standing position. Each subject was instructed to fill his or her lungs as completely as possible and blow the air out as rapidly and completely as possible. Subjects were exhorted to continue the FVC for five or more seconds or until all measurable air had been expelled, as observed on the recording paper. The best FVC effort was used to make all measurements. All figures for pulmonary function in this study were taken directly from the standard recording paper of a Pulmonor Spirometer, which is calibrated to provide BTPS corrected values. Most of the measurements were made during the moderate (70–85°) temperature of February at an altitude of approximately 700 feet.

Cigarette smoking did not exclude a subject from this study. The amount of smoking was recorded and the smokers were compared with nonsmokers. A 'smoker' in this study was any subject who indicated he had smoked one or more cigarettes daily for at least two months. This rather stringent criterion was used because individual cigarette consumption typical of developed countries is very uncommon among these subjects. Among the men, 285 admitted to being smokers. All of the women declared that they did not smoke.

Statistical considerations

From the experience mentioned in the introduction above, associations were expected between some values of pulmonary function and certain covariables such as age, height, and arm span. Whether or not moderate smoking typical of this region of the world was important was to be determined. Extensive analyses of possible associations were done, the aim of which was to establish which covariables were of practical significance. These would have to be taken into account if one were to determine basic characteristics of pulmonary variables in the particular population under study.

Secondly, an analysis of residuals was made. This method fits a regression function of the covariable (for example, height) to some pulmonary measurement (for example, to FVC), then checks that the variability in FVC around the regression function is reasonably constant for all values of height. If so, each observation is then considered not as initially measured but at the 'distance' or 'residual' from the regression function. Once this is done, the totality of residuals is examined to determine in an optimum way certain useful percentiles of their distribution. In practice, a particular measurement of FVC for a subject with known covariables can be transformed to a residual, and then the FVC percentile corresponding to that residual can be determined and the subject can be evaluated regarding how 'high' or 'low' he is after the values of the covariables have been accounted for. In other words, the actual measurement of FVC, as such, is not as important as the relative level of this measurement in comparison to normal people having the same values of the covariables. Examples shown below should make this clear.

The measurements of FVC, FEV_1 and MMF were studied as they may or may not have depended on age, height, and arm span. To do this regression, equations based on age, height, and arm span were calculated for the three variables (FVC, FEV_1 and MMF) in three groups: male smokers, male non-smokers, and female non-smokers. This was done by the stepwise regression procedure in which covariables were added one by one, the one producing the greatest reduction in the residual variance being added at each stage (Dixon, 1975). When the reduction is no longer significant, no more covariables are added.

A decision to develop separate equations for the group of smokers and for the group of non-smokers was prompted by several considerations. Firstly, significant overall differences in the mean values for FEV_1 and MMF between these two groups were found. Secondly, in the regression analysis it became evident that using the smoking status in the analysis resulted in a statistically significantly better fit to the data on MMF, although not for FVC or FEV_1. Its failure to improve practically the prediction equation in the case of FEV_1 in spite of finding significant overall differences suggests that the difference between smokers and non-smokers noted above is a complex matter. It may possibly be related to the strict definition of a 'smoker' in this study. Smoking is apparently on the increase in Pakistan and thus could be an influential factor in future studies. Finally, the usefulness of the results is enhanced by using a single methodology for all the pulmonary functions, even though in some cases smoking may not be a significantly important covariable.

Results

A summary of data collected from the 599 Pakistani men of this study is given in Table 1. There was no apparent difference between smokers and non-smokers in height, arm span, and FVC. However, differences seem to exist in FEV_1 and MMF. These observations are based on averages; the ranges are fairly large and relationships between study variables, covariables, and smoking, where explored, were not always in agreement, as mentioned above.

Similar data for 94 women are shown in

Table 1 *Mean, standard deviation, and range of pulmonary and physical variables measured on 599 Pakistani men, by smoking status*

Variables	*Means*			*Standard deviation*[1]	*Range*	
	All men (n=599)	*Smokers (n=285)*	*Non-smokers (n=314)*		*Smokers*	*Non-smokers*
Pulmonary variables						
FVC (l)	4·02	4·04	4·00	0·59	2·48–6·50	2·20–5·95
FEV_1 (l)	3·16	3·11	3·22	0·49	1·72–5·30	1·90–5·20
MMF (l/s)	3·20	3·01	3·37	0·90	0·95–6·00	1·10–5·20
Covariables						
Age (yr)	28·6	30·4	27·0	9·2	16–65	15–70
Height (in)	66·6	66·6	66·6	2·3	60–73	60–73
Arm span (in)	69·6	69·7	69·5	2·8	60–78	60–78
Amount of smoking						
Cigarette years[2]	—	104·8	—	134·9	0·17–920	—

[1]Of total sample, except for cigarette years.
[2]Number of cigarettes smoked per day × number of years smoked.

Table 2 *Mean, standard deviation, and range of pulmonary and physical variables measured on 94 Pakistani women*

Variables	Mean (n=94)	Standard deviation	Range
Pulmonary variables			
FVC (l)	2·76	0·39	1·58–3·88
FEV_1 (l)	2·28	0·32	1·50–3·28
MMF (l/s)	2·65	0·71	1·00–5·00
Covariables			
Age (yr)	21·8	8·2	15–45
Height (in)	62·4	2·4	55–68
Arm span (in)	64·3	2·8	58–70

Table 2. Large differences between men and women can be seen by comparing Table 2 with Table 1.

The relationships between age, sex, smoking, and the three study variables were examined in Figure 1. The smoker, non-smoker differences look appreciable only for MMF. Associations with age are negative and seem to show that for FVC and FEV_1 teenagers have lower values than young adults while the trend seems linear from about age 25 to about age 55. These observations are similar to the results of studies in normal subjects between 7 and 70 years of age, reported by Berglund *et al.* (1963). The decline beyond age 60 cannot be assessed because of very small numbers of subjects.

Figure 2 shows an analogous graphic study of height, sex, smoking, and the pulmonary variables. The findings are similar except that the association with height is positive rather than negative as with age.

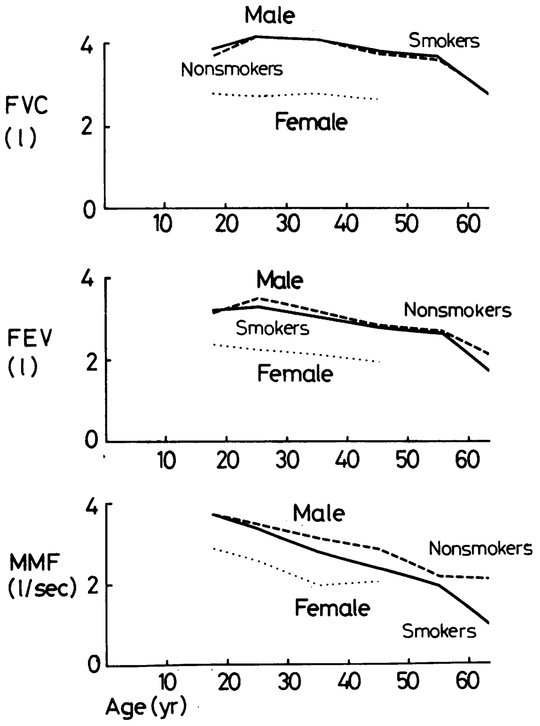

Fig. 1 *Mean values of pulmonary function measurements by age, sex, and male smoking status. Means, based on 10-year intervals, are plotted at mid-interval and joined by straight lines.*

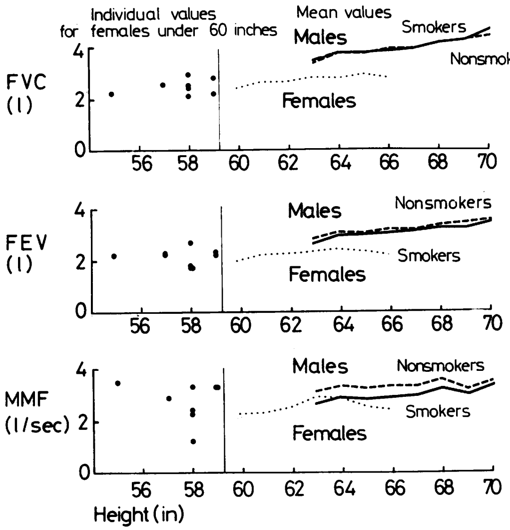

Fig. 2 *Mean values of pulmonary function measurements by height, sex, and male smoking status. Means are plotted at each inch of height. The few female values at height under 60 inches were erratic for MMF and hence individual values were plotted instead of means.*

Height and arm span were highly correlated (r=0·81) and are considered here to be interchangeable.

When the regression results were evaluated separately for each of the dependent variables FVC, FEV_1, and MMF, height and age were always found to be important predictors; arm span was of considerably less importance once height was used. Regression equations developed for age and height and age and arm span appear in Table 3. Note that smoking status was of importance only for MMF. It was kept for FVC and FEV_1 to maintain uniformity in applications.

When smokers alone were studied, height and age were of great importance for all three pulmonary measurements. For non-smokers this was

Table 3 (*a*) *Regression equations for pulmonary variables as linear functions of age and height: male smokers, male non-smokers, and females, age in years and height in inches*[1]

		[1]The coefficient below may be substituted if height measured in centimetres
Male smokers—Aged ≥ 20[2]		
FVC =	−4·9954 −0·0204 Age +0·1453 Ht	0·0572 Ht cm
FEV_1 =	−3·0129 −0·0275 Age +0·1046 Ht	0·0412 Ht cm
MMF =	−1·5272 −0·0523 Age +0·0919 Ht	0·0362 Ht cm
Male non-smokers—Aged ≥ 20[2]		
FVC =	−3·1940 −0·0192 Age +0·1174 Ht	0·0462 Ht cm
FEV_1 =	−0·8858 −0·0240 Age +0·0722 Ht	0·0284 Ht cm
MMF =	2·8429 −0·0379 Age +0·0233 Ht	0·0092 Ht cm
Females		
FVC =	−2·2275 −0·0039 Age +0·0813 Ht	0·0320 Ht cm
FEV_1 =	−0·6899 −0·0147 Age +0·0527 Ht	0·0208 Ht cm
MMF =	1·2931 −0·0383 Age +0·0351 Ht	0·0138 Ht cm

[2]Males under 20 were deleted here because they appear to deviate from the general trends by age and by height of FVC and FEV_1. See Figs 1 and 2.

(*b*) *Expected values of pulmonary variables as linear combination of age and arm span: age in years and arm span in inches*[1]

		[1]The coefficient below may be substituted if arm span measured in centimetres.
Male smokers—Aged ≥ 20		
FVC =	−3·376 −0·019 Age +0·115 Arm span	0·045 Arm span cm
FEV_1 =	−1·642 −0·026 Age +0·080 Arm span	0·032 Arm span cm
MMF =	0·861 −0·051 Age +0·053 Arm span	0·021 Arm span cm
Male non-smokers—Aged ≥ 20		
FVC =	−1·881 −0·018 Age +0·093 Arm span	0·037 Arm span cm
FEV_1 =	−0·047 −0·023 Age +0·057 Arm span	0·022 Arm span cm
MMF =	3·301 −0·038 Age +0·016 Arm span	0·006 Arm span cm
Females		
FVC =	−0·963 −0·006 Age +0·060 Arm span	0·024 Arm span cm
FEV_1 =	0·004 −0·016 Age +0·041 Arm span	0·016 Arm span cm
MMF =	0·973 −0·040 Age +0·040 Arm span	0·016 Arm span cm

not consistent. Height and age were important for FEV_1, but for FVC height and arm span were the top two, and for MMF age was the only significant variable. Nevertheless, in the regression equations developed here, height and age were selected to keep methods uniform and to make the applications simpler with trivial loss of precision.

Discussion

This report gives previously unavailable spirometric prediction formulae for Pakistan. The prediction formulae for FVC and FEV_1 in non-smoking Pakistani men are similar to those found in men in northern India (Jain and Ramiah, 1969). Similar results for FVC were also found in a study of West Pakistani male emigrants to Great Britain (Malik *et al.*, 1972) working in cotton, wool, and asbestos textile mills and a cable-rubber manufacturing firm. Their FEV_1 predictions are somewhat higher than ours and, as they point out, those found in other studies.

Values in the current study were higher than those of more eastern (Calcutta) and southern (Bombay) India (Rao *et al.*, 1961; Raghaven and Nagendra, 1965). Since Lahore, Pakistan, is only 300 miles west and north of Delhi and at similar altitude, it is not surprising that the spirometric formulae for men are similar. Regression equations for vital capacity from several studies are compared in Figure 3.

The Pakistani women were found to have spirometric values more like those of the ethnic groups having lower volumes and flows, as in Bantu (Johannsen and Erasmus, 1968) and other African studies (Femi-Pearse and Elebute, 1971). The values were slightly lower but comparable to those of a study in Delhi (Jain and Ramiah, 1967) but higher than in eastern (Calcutta) and southern (Bombay and Madras) Indian women (Rao *et al.*, 1961; Raghaven and Nagendra, 1965; Mason, 1932–33). These studies are compared to the USA study (Ferris *et al.*, 1965) in Figure 4.

FVC and FEV_1 in Pakistani male smokers do not differ from the values in non-smokers. This may be explained by the relatively low lifetime consumption rate in this developing country. The smoking group included those who smoked more than one cigarette daily for at least two months and the mean lifetime consumption was 134 cigarette-years (6·7 pack years) in a group averaging 30·4 years of age. Only the MMF differed significantly between healthy smokers and non-smokers in similar occupational groups. In North America also the MMF has been reported to be abnormal in vigorous smoking men whose FVC and FEV_1 were in the normal range (McFadden and Linden, 1972). Thus, this measurement should be applied more widely in other parts of the world.

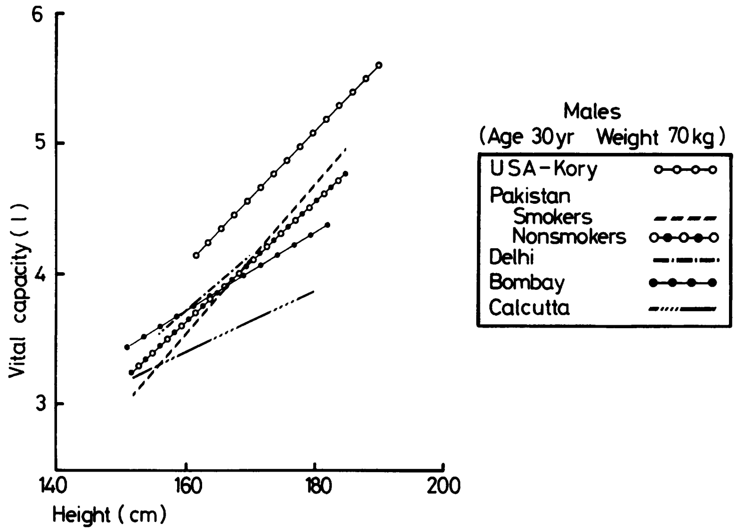

Fig. 3 *Vital capacity as a function of height in Pakistani men aged 30 compared to one USA and three Indian studies.*

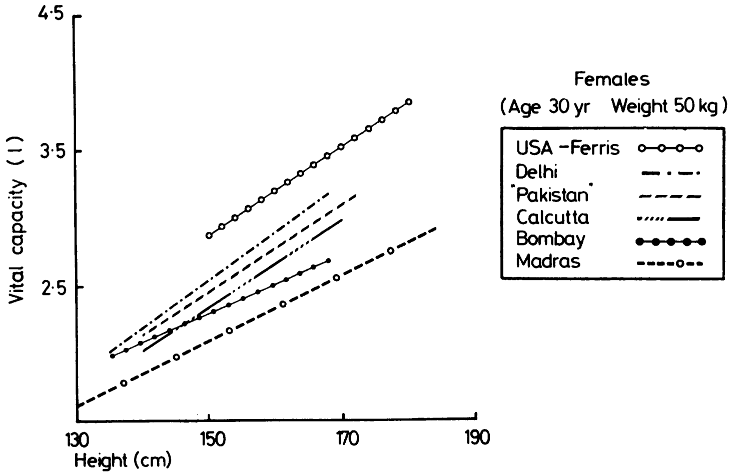

Fig. 4 *Vital capacity as a function of height in Pakistani women aged 30 compared to one USA and four Indian studies.*

Our findings further support the need to establish normal values in men and women in any previously untested ethnic or geographical group before decisions are made about the prevalence of dysfunction relating to disease. The ethnic variation of men and women may also be different, as noted in this report. The measurements in Pakistani men ranked rather high among non-European groups previously reported while those in the women, even though none were smokers, were among the lowest.

We thank Dr. Abdul Quddus, Dr. Najma Sardar Khan, and Mr. Immanuel Khan for their very valuable assistance in the surveys, and Mr. Ken Offord and Mr. Allan Zinsmeister for statistical expertise. Our appreciation also to Dr. Robert E. Hyatt for his advice during the project and the preparation of this report.

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