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Pulmonary function in healthy young adult Indians in Madras

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Abstract

Forced vital capacity, forced expiratory volume in one second, functional residual capacity, residual volume, total lung capacity, and single breath diffusing capacity measurements (effective alveolar volume, carbon monoxide transfer factor, and transfer coefficient) were measured in 247 young healthy adults (130 male, 117 female) aged 15–40 years living in Madras. Subjects were of Dravidian stock, living at sea level with rice as their staple diet. Regression equations were derived for men and women for predicting normal pulmonary function for young adults in South India. The values were similar to those reported for subjects from Western India and lower than those reported for North Indians and caucasians.

Differences in pulmonary function in normal people may be due to ethnic origin, physical activity, environmental conditions, altitude, tobacco smoking, age, height, sex, and socioeconomic status.[1] The wide range of geographical and climatic conditions in a large country such as India may be associated with regional differences in lung function in healthy individuals, as shown in previous studies.[2–6] We have measured pulmonary function, including spirometric indices, static lung volumes, and diffusing capacity indices, in healthy young adults in South India.

Methods

SUBJECTS

We studied 247 ethnic South Indians living in Madras and aged 15–40 years. They included relatives of patients attending the Tuberculosis Research Centre, staff members, manual workers, students, and executives, to obtain a cross section of the normal inhabitants of Madras city. The proportions of subjects in the different income groups were: low (less than 500 rupees a month) 49%, middle (500–1500 rupees) 38%, and high (more than 1500 rupees) 13%, similar to the proportions seen in the general population in Madras city (data obtained from Madras Municipal Corporation on the basis of the 1981 government census). The proportion of subjects who declined to take part in this study was less than 1%. Subjects were eligible for the study if they were ethnic South Indians, had no structural deformity of the thoracic cage, and were free from respiratory infections and had been so for at least three months before the tests. None of the subjects had any cardiorespiratory disease, as assessed by detailed history, physical examination, chest radiography, and 12 lead electrocardiography. Symptomless smokers were included.

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TESTS

Pulmonary function tests were carried out with transfer test model C (P K Morgan, Chatham, UK), readings being obtained from a Data Dec computer. Sex, ethnic identity, standing height to the nearest centimetre without shoes, weight in kilograms, age, smoking habit, occupation, and spirometer temperature were recorded for all subjects before testing. The tests were carried out with the subject seated and with a nose clip applied. The equipment was calibrated fully every day. The coefficient of variation for six subjects studied over a year was less than 1% for forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1), less than 2% for total lung capacity (TLC), alveolar volume (VA), carbon monoxide transfer factor (TLCO), and transfer coefficient (KCO), less than 2·5% for functional residual capacity (FRC), and less than 5% for residual volume (RV). All volumes were expressed in BTPS.

Spirometry

At least three forced vital capacity manoeuvres[7] were obtained for each subject; for FVC and FEV_1 the best two of three tracings had to be within ±5%. The largest of three FVC and FEV_1 values was accepted even if the two volumes did not come from the same curve. The ratio of FEV_1 to FVC was expressed as a percentage.

Static lung volumes

Functional residual capacity, residual volume, and total lung capacity were measured by the closed circuit helium dilution method.[8] Duplicate measurements of FRC were made for each patient and the mean value was used for analysis.[1] Residual volume and total lung capacity were calculated from the kymograph tracing.

Single breath carbon monoxide transfer factor

The single breath carbon monoxide transfer factor[7,8] was measured with a gas mixture containing helium 14%, carbon monoxide 0·288%, and oxygen 18%, the rest being nitrogen (P K Morgan). All subjects attended the clinic at 0730–0800 hours and the single breath measurements were performed after 1200 hours to make sure that none of the smokers had smoked tobacco for at least four hours before the test. This was performed at least in duplicate and values were accepted if the duplicate determinations did not vary by more than 5%. The highest value (expressed in mmol/kPa/min) was used for the analysis. A value for alveolar volume was obtained during the single breath TLCO measurement. KCO was calculated as the ratio of TLCO to VA and expressed in mmol/kPa/min/litre. Measured TLCO and KCO were corrected to a standard haemoglobin (Hb) concentration of 14·6 g/dl by means of the following equation[9]:

$$\text{TLCO corrected for Hb concentration (CTLCO)} = \text{TLCO observed} \times (14{\cdot}6\,a + \text{Hb})/(1 + a)\text{Hb},$$

where Hb is the actual haemoglobin concentration in g/dl and a is 0·7. The KCO corrected for haemoglobin (CKCO) was calculated from CTLCO.

STATISTICAL METHODS

Best fitting cross sectional equations were derived separately for men and women by multiple linear regression analysis. As there was an increase in spirometric and static lung volumes from 15 to 25 years, a plateau from 25 to 35 years, and a decline from 35 years onwards, a quadratic term (age squared) was included in the prediction model. Age^2 and height were entered into the equation for all pulmonary function measurements; age^2-height interactions were tested for significance by means of a stepwise regression procedure. Residuals were calculated and tested for each of these best fitting models for each sex. The goodness of fit of the models was also tested by examining the correlations of residuals with age^2 and height and by inspecting graphs of residuals versus predicted values to confirm the absence of a curvilinear pattern. A dummy variable for smoking (non-smokers = 0, smokers = 1) was introduced into the regression equations to test the effect of smoking in men.

All analyses were performed with the SPSS/PC statistical computing package on an IBM/XT compatible personal computer. Unless otherwise specified, the term significant is used to imply a p value of less than 0·05.

Results

The mean (SD) height was 166 (7·6) cm in men and 152 (5·3) cm in women, and weight was 53·4 (11·6) and 44·7 (9·3) kg. The mean haemoglobin concentration in men was 14·3 (1·7) g/dl and only two had values below 11 g/dl. In women, however, it was 10·8 (1·6) g/dl and 27 (23%) had a concentration of less than 10 g/dl. All women were non-smokers. Among the 45 male smokers eight had stopped smoking at least one year before the tests; 26 had smoked three to 10 cigarettes or bidis (sun cured tobacco packed loosely inside a vegetable leaf) a day for less than five years, and 11 had smoked more than 20 cigarettes or bidis a day for more than five years.

In men the mean FVC was 3·53 (0·68) litres, TLC 4·76 (0·86) l, and TLCO 9·40 (2·00) mmol/kPa/min; in women the mean FVC was 2·37 (0·36) l, TLC 3·43 (0·45) l, and TLCO 6·34 (1·10) mmol/kPa/min. Almost all measurements reached a peak in the 20–24 age group, remained at that level up to the age of 30–34 years, and then showed a mild decline. RV and RV/TLC%, however, showed a small rise in the 35–40 year age group. FEV_1/FVC% showed a gradual decline with increasing age in both sexes. Additional data are available on request.

Both age and height in men showed a significant positive correlation with FVC, FRC, RV, TLC and VA; the correlations were stronger with height (table 1). FEV_1 and TLCO were significantly correlated with height; KCO showed a significant negative correlation with age. In women FVC, FEV_1, FRC, TLC, and VA showed a significant positive correlation with height (table 2). There was a negative

Table 1 Regression relationships for predicting indices of lung function from age^2 (y) and height (cm) in healthy young adult South Indian men

Measurement	Mean	SD	Constant	Regression coefficients†		Multiple R	Standard error	Correlation coefficients	
				Age^2	Height			Age	Height
FVC	3·53	0·68	−6·857	—	0·062	0·71	0·481	0·275*	0·692**
FEV_1	3·02	0·60	−6·195	−0·00023	0·057	0·72	0·415	0·129	0·650**
FEV_1/FVC %	85·87	7·05	76·695	−0·00613	0·080	0·36	6·638	−0·355**	−0·089
FRC	2·63	0·61	−5·341	0·00035	0·047	0·65	0·470	0·450**	0·621**
RV	1·36	0·50	−3·596	0·00043	0·028	0·61	0·399	0·474**	0·533**
TLC	4·76	0·86	−8·267	0·00060	0·076	0·76	0·564	0·510**	0·736**
RV/TLC %	27·82	5·93	42·492	0·00777	−0·127	0·52	5·117	0·490**	0·056
VA	4·37	0·88	−6·870	0·00062	0·065	0·66	0·664	0·474**	0·688**
TLCO	9·40	2·00	−11·236	−0·00040	0·126	0·48	1·772	0·222	0·448**
KCO	2·17	0·38	3·126	−0·00014	−0·005	0·41	0·347	−0·259*	−0·247
CTLCO	9·15	1·69	−8·666	−0·00009	0·110	0·45	1·519	0·178	0·439**
CKCO	2·13	0·32	3·658	−0·00023	−0·0075	0·47	0·286	−0·434**	−0·371**

†Smoking coefficient for KCO = −0·164; smoking coefficient for CKCO = −0·217.
*p < 0·01; **p < 0·001.
FVC—forced vital capacity; FEV_1—forced expiratory volume in one second; FRC—functional residual capacity; RV—residual volume; TLC—total lung capacity; VA—alveolar volume; TLCO—carbon monoxide transfer factor; KCO—transfer coefficient.

Table 2 Regression relationships for predicting indices of lung function from age² (y) and height (cm) in healthy young adult South Indian women (non-smokers)

Measurement	Mean	SD	Constant	Regression coefficient: Age²	Regression coefficient: Height	Multiple R	Standard error	Correlation coefficients: Age	Correlation coefficients: Height
FVC	2·37	0·36	−2·883	—	0·035	0·50	0·325	0·033	0·496**
FEV_1	2·08	0·33	−1·900	—	0·026	0·40	0·304	−0·098	0·397**
$\frac{FEV_1}{FVC}$%	87·53	6·17	94·917	−0·00734	−0·011	0·42	5·639	−0·366**	−0·029
FRC	1·98	0·37	−2·119	0·00022	0·026	0·42	0·340	0·135	0·388**
RV	1·06	0·26	−0·324	0·00017	0·008	0·28	0·256	0·177	0·153
TLC	3·43	0·45	−2·307	0·00024	0·036	0·46	0·404	0·143	0·457**
$\frac{RV}{TLC}$%	30·65	5·94	42·377	0·00355	−0·095	0·22	5·844	0·184	−0·165
VA	3·15	0·46	−2·608	—	0·038	0·42	0·422	−0·019	0·416**
TLCO	6·34	1·10	2·076	−0·00068	0·032	0·26	1·072	−0·272*	0·072
KCO	2·03	0·30	4·293	−0·00024	−0·014	0·37	0·279	−0·318*	−0·312*
CTLCO	7·34	1·21	0·832	−0·00113	0·049	0·38	1·127	−0·347**	0·144
CKCO	2·34	0·31	4·908	−0·00034	−0·015	0·48	0·272	−0·226	−0·128

*$p < 0·01$; **$p < 0·001$.
Abbreviations as in table 1.

correlation between TLCO and age, and between KCO and age and height.

As the addition of a dummy variable for smoking did not have any significant effect on any of the pulmonary function measurements except KCO and CKCO, the coefficients for smoking were introduced into the prediction equations only for KCO and CKCO measurements.

The multiple regression equations for men and women based on age² and height are shown in tables 1 and 2. Predicted values are derived from these regression equations as follows:

Predicted value = K + (age² in years × age² coefficient) + (standing height in cm × height coefficient),

where K is the constant. Smoking coefficients are added for KCO and CKCO to derive the predicted values in smokers.

The predicted values of various pulmonary function measurements obtained from these regression equations for subjects of specified age (30 years) and height (165 cm for men, 155 cm for women) are compared with those from other studies in tables 3 and 4.

Discussion

Establishing regression equations to predict various measurements of normal lung function on a regional basis in a country like India, with wide variations in geography, climate, food habits, and ethnic groups, is important for the management of patients with various cardiopulmonary diseases. Results of comprehensive lung function studies in normal subjects are available for North and West Indian subjects.[2 3 6 10] There have not, however, been any comparable studies of lung function, including lung volumes and diffusing capacity measurements, in South Indians of Dravidian stock living in a tropical climate at sea level with rice as their staple food. Previous studies of ventilatory capacity in South Indians had shown that the subjects had lower values for ventilatory capacity and expiratory flow[4 5 11] than subjects from the Western world and North Indians.

Table 3 Predicted pulmonary function values from various studies in men of specified age (30 y) and height (165 cm)

Location and reference	FVC (l)	FEV_1 (l)	RV (l)	FRC (l)	TLC (l)	VA (l)	TLCO (mmol/kPa/min)	KCO (mmol/kPa/min/l)	CTLCO (mmol/kPa/min)	CKCO (mmol/kPa/min/l)
Indians										
Jain[2] (N India)	3·95	—	1·50	2·80	5·35	—	—	—	—	—
Udwadia[6] (W India)	3·54	2·80	1·36	2·43	4·67	—	8·60	—	—	—
Kamat[11] (S India)	3·34	2·84	—	—	—	—	—	—	—	—
Vijayan (this study)	3·37	2·92	1·43	2·62	4·74	4·32	9·51	2·17	9·51	2·21
Caucasions										
Cotes[8]	4·44	3·67	—	—	5·87	—	10·09	1·81	—	—
Goldman[13]	4·29	—	1·52	3·30	5·89	—	—	—	—	—
Chinese										
DaCosta[16]	3·68	3·11	1·41	3·05	5·05	—	—	—	—	—
Others										
Woolcock[1] (New Guinea coast)	3·59	3·15	—	—	—	—	—	—	—	—
Miller[15]										
Guyanan Indians	3·47	2·91	—	—	—	—	—	—	—	—
Guyanan Negroes	3·64	3·07	—	—	—	—	—	—	—	—
Highlanders										
Woolcock[1]	3·90	3·34	—	2·86	5·13	—	—	—	—	—

Abbreviations as in table 1.

Table 4 Predicted pulmonary function values from various studies in women of specified age (30 y) and height (155 cm)

Location and reference	*FVC (l)*	*FEV$_1$ (l)*	*RV (l)*	*FRC (l)*	*TLC (l)*	*VA (l)*	*TLCO (mmol/kPa/min)*	*KCO (mmol/kPa/min/l)*	*CTLCO (mmol/kPa/min)*	*CKCO (mmol/kPa/min/l)*
Indian										
Jain[3] (N India)	2·78	—	1·22	2·13	3·95	—	—	—	—	—
Udwadia[6] (W India)	2·61	2·02	1·16	1·92	3·55	—	6·80	—	—	—
Kamat[11] (S India)	2·34	1·89	—	—	—	—	—	—	—	—
Vijayan (this study)	2·54	2·13	1·07	2·11	3·49	3·28	6·42	1·91	7·41	2·28
Caucasians										
Goldman[13]	3·16	—	1·17	2·63	4·52	—	—	—	—	—
Hall *et al*[18]	3·48	2·81	1·28	2·92	4·77	—	9·00	—	—	—
Chinese										
DaCosta[16]	2·70	2·33	1·18	1·90	3·97	—	—	—	—	—
Others										
Woolcock[1] (New Guinea coast)	2·61	2·27	—	—	—	—	—	—	—	—
Miller[15]										
New Guyanan Indians	2·71	2·17	—	—	—	—	—	—	—	—
New Guyanan Negroes	2·81	2·30	—	—	—	—	—	—	—	—
Highlanders										
Woolcock[1]	3·07	2·53	—	2·49	4·42	—	—	—	—	—

Abbreviations as in table 1.

The positive and strong correlations between various indices of lung size (FVC, FRC, TLC, and VA) and height in both sexes in this study are similar to those reported in previous studies.[1 2 6 11–13] There was no age related decline in FVC in either sex in this study but FEV$_1$ showed an age related decline in men, though not in women. In a study of 250 non-smoking healthy Pakistanis from an area with extremely low levels of air pollution Ayub *et al* found that in men age made only a slight contribution to change in FVC and FEV$_1$.[14] The absence of any age related decline in FVC has also been observed in North Indians.[2] FVC, FEV$_1$, and FEV$_1$/FVC% in both sexes in our study are similar to values reported by Udwadia *et al* in West Indians[6] and by Kamat *et al* in South Indians.[11] They are also similar to those of Guyanan Indians,[15] coastal dwellers of New Guinea,[1] and Chinese,[16] but are lower than those reported from North India[2 3] and from Western countries.[12 13 17–20]

Static lung volumes (TLC and FRC) in both sexes were similar to those seen in West Indians,[6] but lower than those of North Indians.[2 3] Lung volumes are about 15–20% lower in South Indians than in Western subjects.[13 17] Age was associated with an increase in TLC in men but had a minimal effect in women. Our findings are similar to those of other studies from India[2 6] and in highlanders from New Guinea.[1] Earlier observations suggested that RV may not show ethnic variability[8] and, in keeping with this, RV in our study was similar to values reported from studies of Indian,[2 6] Western,[13] and Chinese subjects.[16] The early closure of peripheral airways in subjects with small lungs may be responsible for the similar RV values in the various groups despite different lung volumes.

The single breath transfer factor (TLCO) in men in our study was similar to values seen in West Indians[6] and similar to[21] or slightly less (6%) than European values.[8] Though TLCO values in South Indian and British men were similar,[8] the British subjects had a higher alveolar volume and hence lower KCO values. Previous reports found no difference in KCO between the sexes[22 23] and we may reasonably assume that the gas transfer per unit lung volume is similar in men and women. The fact that KCO was 10% lower in women in our study than in men may be due to the fact that more women (23%) had a haemoglobin concentration below 10 g/dl, only two men having a concentration less than 11 g/dl. KCO values were similar in men and women after correction for haemoglobin concentration. The finding of similar TLCO values in men in the present study and in Western studies, despite 15–20% lower values for lung volumes, points to the need for further study.

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