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REFERENCE VALUES AND PREDICTION EQUATIONS FOR MAXIMAL EXPIRATORY FLOW RATES IN-NON-SMOKING NORMAL SUBJECTS IN MADRAS

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Abstract : Maximal Expiratory Flow Rates such as Peak Expiratory Flow Rate (PEFR). rates at 25%, 50% and 75% of forced vita) capacity (V max 25%, V max 50% and V max 75%) and forced expiratory flow during the middle half of forced vital capacity (FEF 25-75%) were measured in 273 healthy non-smoking adults (144 males, 129 females) aged 15-63 years living in Madras. Regression equations were derived for men and women for predicting maximal expiratory flow rates for adults in South India. Expiratory Flow Rates at lower lung volumes in men were similar to those reported for caucasians, but higher than those reported for western Indian Subjects. However, in women the flow rates were similar to those of western Indians and lower than those of caucasians, probably due to indoor air pollution since childhood. These data may suggest that expiratory flow rates at lower lung volumes may not show ethnic variability.

Key words : expiratory flow rates lung function prediction equations

INTRODUCTION

As differences in pulmonary functions are known to occur due to various reasons such as ethnic origin, environmental conditions and altitude (1), we had reported regression equations for men and women for predicting normal pulmonary functions (spirometry, lung volumes and diffusing capacity measurements) for young adults in South India (2). However, such regression equations are not currently available for maximal expiratory flow volume measurements in healthy South Indian subjects, although such a study had been reported for western Indian subjects (3). We, therefore, undertook a study to derive regression equations for predicting normal expiratory Flow-volume measurements in healthy South Indian subjects.

Subjects

We studied 273 Non-smoking Indians (144 males and. 129 females) living in Madras and aged 15-63 years (mean age, males 29.9±12.7 yr and females 30.l±9.4 yr). They included relatives of patients attending the Tuberculosis Research Centre, staff members, manual workers and executives, to obtain a cross section of the normal inhabitants of Madras city. 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 test. None of the subjects had any cardio-respiratory disease, as assessed by detailed history, physical examination, chest radiography and 12 lead electrocardiography.

Tests

Maximal Expiratory Flow Rates such as peak expiratory flow rate (PEFR), rates at 25%, 50% and 75% of Forced Vital Capacity (V max 25%, V max 50% and V max 75%) and forced expiratory flow during

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the middle half of forced vital capacity (FEF 25-75%) were carried out with Transfer Test Model C (PK Morgan, Chatham UK), readings being obtained from a Data Dec Computer. Sex, ethnic identity, standing height to the nearest centimeter 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 subjects seated and with a nose clip applied. The equip ment was calibrated fully every day. The coefficient of variation of six subjects studied over one year was less than 3% for PEFR, FEF 25-75% and V max 25%; <5% for V max 50% and 10% for V max 75%.

Maximal Expiratory Flow Rates: Maximal expiratory flow-volume loops were recorded by asking the subject to take a deep breath until he/she breathed in to total lung capacity (TLC) and to wrap his/her mouth tightly around a mouth piece, and on a given signal to breath out to residual volume, and finally suck it all back in again as fast as possible to TLC, taking care to keep his/her back against the chair-back all of the time (4). At least three such flow-volume loop (F-V loop) manoeuvres were obtained for each subject. The highest value (5) obtained from any of the three tracings was used for calculation of PEFR. Values of FEF 25-75%, V max 25%, V max 50% and V max 75% were derived from the single best test and the best test was defined as the one with the largest sum of FEV1 and FVC (6,7).

Statistical methods

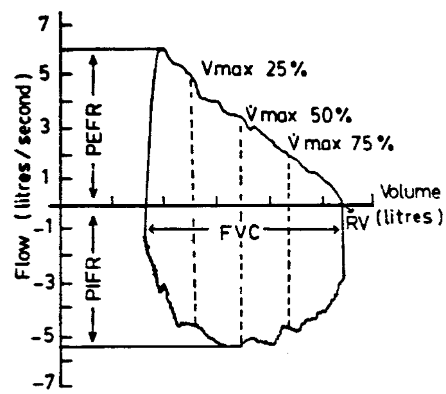
Best fining cross sectional equations were derived separately for men and women by multiple linear regression analysis. Age, height and weight were entered into the equation for all expiratory flow measurements. Age, height and weight interactions were tested for significance by means of stepwise regression 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 correlations of residuals with age, height and weight and by inspecting groups of residuals versus predicted values to confirm the absence of a curvilinear pattern.

All analysis were performed with the SPSS/PC statistical computing packagee on an IBM/XT compatible personal computer. Unless otherwise stated, the term significant is used to imply a P value of less than 0.05.

RESULTS

The mean (SD) height was 166.1 (7.7) cm in men and 151.8 (5.8) cm in women, and weight was 56.0 (12.7) and 45.7 (9.1) kg. In men, the mean FVC was 3.42 (0.64) litres, FEV1 2.92 (0.60) litres and FEV1/FVC % 85 (7.2); in women the mean FVC 2.30 (0.35) litres, FEV1 1.99 (0.31) litres and FEV1/FVC % 86.8 (6.4).

Both height and weight in men showed significant positive correlations with PEFR, FEF 25 -75%, V max 25% and V max 50%. Age had significant negative correlation with FEF 25-75% and V max 50% in addition. V max 75% had significant negative correlation with age and positive correlation with height in men (Table 1). In women, height and weight had significant positive correlations with PEFR and V max 25%. FEF 25-75% and V max 50% had significant negative correlation with age and positive correlation with height. Age was negatively correlated with V max 75% in women (Table II). Flow Volume loop recorded from a normal non-smoking South Indian subject is shown in Fig. 1. Typical F-V loops obtained from patients with bronchial asthma and chronic obstructive airways disease are given in Fig. 2 and 3.



PEFR = Peak expiratory flow rate
PIFR = Peak inspiratory flow rate
FVC = Forced vital capacity
RV = Residual volume

Fig. 1 : Flow-Volume Loop in a normal non-smoking S. lndian subject.

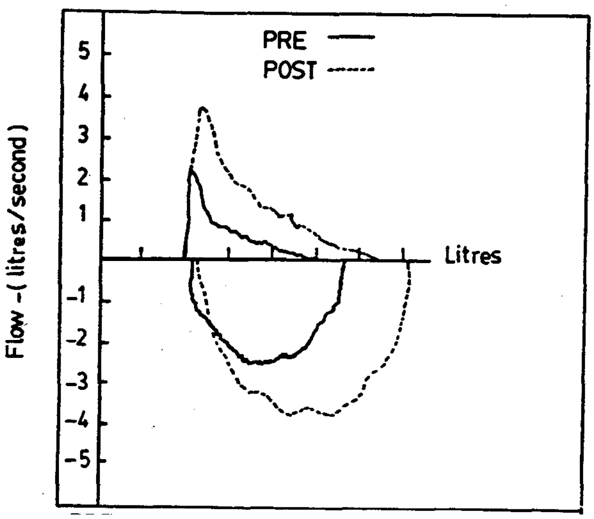


Fig. 2 : Flow-Volmnc Loop in patient with bronchial asthma.

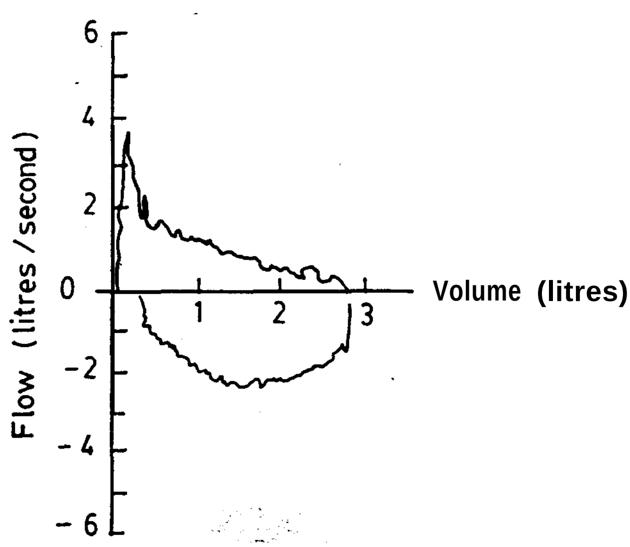


Fig. 3 : Flow-Volume Loop in a patient with chronic obstructive airways disease.

The multiple regression- equations for men and women based on age, height and weight are shown in Tables I and II. In order to have homogenous groups and also to eliminate the influence of growth, separate regression equations were derived for the age group 15-24 years and 25-63 years in both sexes and

TABLE I: Regression relationships for predicting maximal expiratory flow rates (litres/second) for age group 15-63 years from age (y), height (cm) and weight (kg) in healthy South Indian men.

Measurement	*Mean*	*SD*	*Constant*	*Regression coefficients*			*Multiple R*	*Standard Error*	*Correlation coefficients*		
				Age	*Height*	*Weight*			*Age*	*Height*	*Weight*
PEFR	7.21	1.87	−5.837	−0.017	0.064	0.054	0.553	1.574	0.023	0.504**	0.495**
V Max 25%	5.80	1.72	−5.163	−0.027	0.054	0.051	0.549	1.455	−0.060	0.454**	0.458**
V Max 50%	4.01	1.28	−2.969	−0.033	0.036	0.037	0.544	1.087	−0.210*	0.423**	0.416**
V MAX 75%	1.77	0.90	–4.846	–0.033	0.046	–	0.568	0.749	–0.426**	0.354**	0.136
FEF 25-75%	3.96	1.18	–4.626	–0.031	0.048	0.029	0.587	0.966	–0.244*	0.474**	0.411**

*P<0.01; **P<0.001

PEFR : Peak Expiratory Flow Rate

V max 25%, V max 50%, V max 75% : Maximal expiratory flow rates at 25%, 50% and 75% of Forced Vital Capacity.

FEF 25-75%: Forced Expiratory Flow during the middle half of Forced Vital Capacity.

TABLE II: Regression relationships for predicting maximal expiratory flow rates (litres/second) for age group 15-63 years from age (y), height (cm) and weight (kg) in healthy South Indian women.

Measurement	*Mean*	*SD*	*Constant*	*Regression coefficients*			*Multiple R*	*Standard Error*	*Correlation coefficients*		
				Age	*Height*	*Weight*			*Age*	*Height*	*Weight*
PEFR	4.42	1.04	–0.179	–0.006	0.025	0.021	0.275	1.013	–0.118	0.230*	0.230*
V Max 25%	3.64	1.03	–3.934	–0.004	0.045	0.019	0.360	0.970	–0.011	0.322**	0.269*
V Max 50%	2.69	0.75	–0.075	–0.020	0.020	0.007	0.320	0.699	–0.241*	0.225*	0.073
V MAX 75%	1.35	0.58	0.346	–0.027	0.012	–	0.473	0.512	–0.457**	0.171	–0.159
FEF 25-75%	2.68	0.70	–2.001	–0.015	0.034	–	0.368	0.653	-0.239”	0.305**	0.113

*P<0.01 ** P< 0.001
Abbreviations as in Table I.

results are shown in Tables III and IV. Predicted values are derived from the regression equations as follows:

Predicted values = K + (age in years x age coefficient) + (standing height in cms x height coefficient) + (weight in kg x weight coefficient), where K is the constant

TABLE III: Regression equations for predicting maximal expiratory flow rates (litres/second) for age group 15-24 years from age (y), height (cm) and weight (kg).

	Mean	*SD*	*Constant*	*Regression coefficient*			*Multiple R*	*Standard Error*
				Age	*Height*	*Weight*		
Males (*n : 67)*								
PEFR	6.93	1.88	–11.939	0.155	0.096		0.562	1.576
V max 25%	5.77	1.71	–11.181	0.190	0.081		0.577	1.416
V max 50%	4.20	1.40	–9.109	0.189	0.059		0.584	1.153
V max 75%	2.14	0.88	–6.391	0.088	0.042		0.559	0.737
FEF 25-75%	4.16	1.28	–5.795	0.140	0.036	0.027	0.654	0.987
Females (n:37)								
PEFR	4.25	1.16	–1.299	0.035	0.017	0.054	0.317	1.145
V max 25%	3.41	0.96	–1.223	–0.021	0.016	0.064	0.394	0.924
V max 50%	2.83	0.83	0.153	0.020	0.003	0.045	0.313	0.824
V max 75%	1.63	0.58	–1.345	0.011	0.015	0.011	0.216	0.593
FEF 25-75%	2.77	0.76	–0.921	0.013	0.012	0.037	0.319	0.754

Abbreviations as in Table I.

TABLE IV : Regression equations for predicting maximal expiratory flow rates (litres/second) for age group 25-63 years from age (y), height (cm) and weight (kg).

	Mean	*SD*	*Constant*	*Regression coefficients*			*Multiple R*	*Stanard Error*
				Age	*Height*	*Weight*		
Males (n : 77)								
PEFR	7.46	1.84	–6.558	–0.047	0.677	0.049	0.557	1.559
V max 25%	5.82	1.74	–7.276	–0.039	0.068	0.053	0.561	1.472
V max 50%	3.84	1.15	–3.706	–0.034	0.043	0.028	0.537	0.992
V max 75%	1.45	0.81	–4.018	–0.029	0.040		0.494	0.710
FEF 25-75%	3.80	1.07	–5.521	–0.033	0.055	0.023	0.592	0.880
Females (n:92)								
PEFR	4.48	0.99	0.320	–0.0196	0.027	0.015	0.310	0.958
V max 25%	3.74	1.04	–5.155	–0.0161	0.062		0.392	0.969
V max 50%	263	0.68	–0.445	–0.0226	O.025		0.371	0.640
V max 75%	1.23	0.53	–0.262	–0.0242	0.019	–0.011	0.475	0.476
FEF 25-75%	266	0.68	–1.955	–0.0250	0.036		0.465	0.606

Abbreviations as in Table L

The predicted values of various expiratory flow rates obtained from these regression equations for subjects of specified age (30 years), height (165 cms for men, 155 cms for women) and weight (55 kg for men, 45 kg for women) are compared with those from other studies in Tables V and VI.

TABLE V : Maximal Expiratory Flow Rates from various studies in men of specified age (30 years), height (165 cm) and weight (55 kg).

Reference	*PEFR(l/s)*	*V max 25% (l/s)*	*V max 50% (1/s)*	*V max 75% (l/s)*	*FEF 25-75% (l/s)*
Udwadia[3]	7.3	–	3.9	1.6	3.2
Bass[8]	7.7	7.1	5.0	1.9	–
Knudson[9]	–	–	4.6	1.9	4.0
Amin[10]	7.1	–	–	–	–
Natarajan[11]	8.4	–	–	–	–
Ayub[12]	8.6	7.0	4.4	1.6	–
Vijayan (This study)	7.2	5.7	3.9	1.8	4.0

Abbreviations as in Table L

TABLE VI : Maximal Expiratory Flow Rates from various studies in women of specified age (30 years), height (150 an) and weight (45 kg).

Reference	*PEFR(l/s)*	*V max 25% (1/s)*	*V max 50% (l/s)*	*V max 75% (1/s)*	*FEF 25-75% (1/s)*
Udwadia[3]	4.9	–	3.1	1.4	2.7
Bass[8]	5.7	5.5	4.5	1.9	–
Knudson[9]	–	–	3.8	1.8	3.2
Amin[10]	4.5	–	–	–	–
Natarajan[11]	6.1	–	–	–	–
Ayub[12]	3.9	3.8	2.8	1.3	–
Vijayan (This study)	4.5	3.8	2.7	1.4	2.8

Abbreviations as in Table I.

DISCUSSION

The detection of pulmonary function abnormalities before clinical symptoms or signs develop helps in early diagnosis and treatment, thus helping in halting the progression of disease. The maximal expiratory flow rates at specific lung volumes recorded during a flow-volume loop manoeuvre especially the terminal segment of the curve can be utilised as useful screening tests for early detection of pulmonary function abnormalities (8). While setting up a pulmonary function laboratory, the most important test to be established initially is flow-volume loop measurements (4). These factors along with the observation that differences in pulmonary function may be due to various reasons especially goegraphic differences (1), emphasise the need for establishing regression equations to predict instantaneous flow rates at specific lung volumes on a regional basis in a subcontinent like India.

The significant negative correlation of age with expiratory flow rates in both men and women in this study is similar to the findings reported in earlier studies (3.8). suggesting that there will be an age-related decline in these measurements as age advances. We had shown previously that pulmonary function measurements such as spirometry, lung volumes and diffusing capacity measurements in South Indians were similar to those reported for subjects from Western India, but lower than those for North Indians and Caucasians (2).

A similar study of maximal expiratory flow-volume curve in normal subjects had been reported in Western Indians living in Bombay (3). Expiratory flow rate at higher lung volumes (PEFR) in males in the present study was similar to that of subjects from Bombay. However. the flow rates at lower lung volumes (V max 75% and FEF 25-75%) were higher in our study subjects and comparable to those reported in Caucasians (8,9). On the other hand, in females, the flow rates at lower lung volumes were similar to those of subjects from Bombay (3) and lower than those of Caucasians (8, 9). The Peak expiratory flow rate in both sexes in this study was similar to those reported by Amin and Pande (10), but lower than those published by Natarajan (11) and Knudson (9). In a previous study in normal Pakistanis (12), it had been found that expiratory flow rates at high lung volumes in men were similar to those of European and American studies, and it had been suggested that either elastic recoil of the lung at a given lung volume in men was greater in Pakistanis and/or large airways resistance was high. They had also noticed that maximal expiratory flow rates in women were lower than those reported in European populations and thought it to be due to their smaller lung volumes.

Since the early segment of the maximal expiratory flow volume loop is effort dependent, flow rates in this part are less reproducible and co-operation from the patients is required for optimal results (13). On the other hand, the terminal segment of the maximal flow volume loop is effort- independent, and maximal flow in this part is governed by the elastic recoil of the lungs and cross-sectional area of the airways between alveoli and the airways in which dynamic compression occurs. The flow rates in the terminal portion of the expiratory F-V loop are therefore, considered to reflect the changes in small airways, and F-V curves obtained after a week effort may also thus, provide information regarding flow rates in small airways (13). However, the flow rates in the terminal portion of the flow-volume curves have high coefficients of variation, but the curvilinearity of the F-V curve to the volume axis in airway obstruction is reproducible. Separate F-V loops recorded while breathing air and a mixture of helium (80%) and oxygen (20%) reduce the intersubject variability by using the subject as his own control (14). The volume at which flow is same for air and helium/ oxygen mixture during comparable forced expiratory manoeuvres (volume of isoflow) is considered as one of the best tests of small airway dysfunction (14).

It had been suggested that environmental pollution especially in a city like Bombay (3) may produce silent disease of the small airways resulting in lower V max at lower lung volumes. The higher V max at lower lung volumes in non-smoking males from Madras compared to Bombay subjects may, therefore, be due to comparatively low levels of environmental pollution in Madras city. The similar flow rates (V max 75% and FEF 25-75%) in females from Madras and Bombay may then, be due to the domestic (Indoor) air pollution, as these women rely on biomass fuels (wood, crop residues and animal dug) for cooking since childhood (15). Expiratory flow rates at lower lung volumes are reduced as a result of flow limitations in small airways

(8). Small airways are defined as those with diameter less than 2 mm (16). Therefore, flow rates in airways less than 2 mm diameter in normal subjects should be theoretically similar in all ethnic groups, as revealed by this study. Similarly, there should also be no differences in flow rates at lower lung volumes between sexes and this has been brought out by similar V max 75% in both sexes in studies reported by Bass and Knudson (8, 9). More studies are required to clarify these points.

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