ORIGINAL ARTICLE

Spirometric Studies in Malaysians between 13 and 69 Years of Age

R. Singh, PhD
H.J. Singh, PhD
R.G. Sirisinghe, MRCP
Department of Physiology, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan Darul Naim

Summary

Spirometry was performed on 1,999 subjects (1,385 males and 614 females) ranging in age from 13 to 69 years and comprising of all the main races in Malaysia. They were divided into 6 age groups. Mean forced vital capacity (FVC) in the males and females was 3.49±0.02 L and 2.51±0.02 L respectively. Both FVC and FEV_1 correlated negatively with age. Regression analysis on data between the ages of 20 to 69 years revealed an age-related decline in FVC of about 30 ml per year of life in the males and 22 ml per year in the females. Multiple stepwise regression of the data for the prediction of an individual's FVC above the age of 20 years gave an equation for the males:

$$FVC=0.0407\ (height)-0.0296\ (age)-2.343\ L$$

and for the females:

$$FVC=0.031\ (height)-0.022\ (age)-1.64\ L.$$

Predicted FVC values derived from equations based on other populations were considerably higher than the observed mean in this study, reemphasising the need to be cautious when applying formulae derived from one population to another. Grossly erroneous conclusions may be reached unless predicted equations for lung-function tests for a given population group are derived from studies based upon the same population group.

Key words: Forced vital capacity, population sample, prediction formulae, reference values.

Introduction

Numerous reports have been published over the years, of spirometry values in various populations. Most of these have dealt with Europeans[1-4], North American population[5-6] and Indians from the subcontinent[7-9]. A few studies have also been made on Asian Chinese[10-12] and other non-Caucasians[13]. These have been obtained with various methods and some have been based on studies of selected groups of individuals. There have also been a few reports of similar studies in healthy Malaysians. These have, however, been limited to a few screening tests on small groups of subjects[14-15].

In view of the paucity of normal data availability and the desirability for each country or population group to establish its own reference values reflective of the character of its population, a further statistically analysed study of pulmonary functions in healthy Malaysians seemed relevant, as very little can be gleaned from studies of Chan and Raman[14] and Ahmad *et al*[15] in terms of deriving a reliable reference standard for the Malaysian population.

The present study therefore aims to determine the lung parameters in normal Malaysians and to ascertain whether there are differences between lung function measurements of Malaysians and those of other population groups. An attempt is also made to derive reliable prediction formulae for forced vital capacity in Malaysian subjects. A comparison of the measured and predicted values between this and other studies has been made for males and females.

Materials and Methods

A total of 1,999 healthy volunteers (1,385 males and 614 females), ranging in age from 13 to 69 years, participated in this study. The study population consisted of all the main races in Malaysia and from as wide a socio-economic strata as possible. Their anthropometric data and ethnic breakdown are presented in Table I. The population studied consisted of both smokers and non-smokers. All subjects completed an MRC modified questionnaire[16] on respiratory symptoms, past medical history, smoking and occupational history. They were all considered to be in good health at the time of the study and had no history of any chronic respiratory ailments as defined by the Medical Research Council (1965)[17]. Age was recorded to the nearest year; height was measured with the subject standing barefoot to the nearest 0.5 cm using a standiometer and weight (in light street clothes) was recorded to the nearest 0.5 kg.

Forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) were measured with a rubber rolling seal volume-displacement dry spirometer (Vicatest VCT, Mijnhardt), which was assessed to have a good correlation with the Stead-Wells water-sealed spirometer[18]. The Stead-Wells spirometer is recommended as the reference spirometer by the Committees on Environmental Health and Respiratory Physiology of the American College of Chest Physicians[19]. FEV% (FEV_1 expressed as percentage of FVC) was also calculated. For the measurement of FEV_1 and FVC, restrictive garments were removed. Each subject was asked to inhale deeply in the standing position, and, with the nose clamped, blow rapidly and completely as possible into a previously calibrated spirometer. The spirometers were calibrated with the same calibrator before and after each day's measurements. The procedure was explained and demonstrated to each subject. Subjects were encouraged to attain maximum effort and 3 measurements were made at 1 minute intervals. The average of 2 highest measurements were taken as the most representative of the subject's ability. Ambient temperature was recorded for each set of tracings taken during the study. FVC and FEV_1 readings were corrected to body temperature and pressure saturated with water vapour (BTPS).

Mean values with their standard error of mean (SEM) were calculated for the whole group and for the age categories. Statistical analysis was performed by Student's t-test, analysis of variance (ANOVA) and by linear regression analysis. Statistical significance was accepted at $p<0.05$.

Results

Anthropometric data for male and female subjects are presented in Table I. Statistical analysis revealed significant differences in height and weight between the different age groups in males and females (males: $p<0.001$ and $p<0.001$ respectively; females: $p<0.01$ and $p<0.001$ respectively). Height was significantly lower and weight was significantly higher in the older age groups in both sexes. Table I also shows that, for each age category, women were generally shorter (by 6.6%) and lighter (by 17.4%) than their male counterparts.

Pulmonary functions as assessed by FEV_1, FVC and FEV% revealed a progressively lower value with advancing age groups in both males and females (Table II). Mean forced vital capacity in the males of group F was 38.5% lower than that of group A (Table II). Similarly, in females, mean FVC in group F was some 42.6% lower than that of group A (Table II). Mean FVC was approximately 28% lower in females than males. FEV_1 and FEV% too were found to be significantly lower with increasing age in both sexes ($p<0.001$ and $p<0.001$ in males and females respectively).

Table I
Mean values and standard error of mean for age, height and weight including ethnic group distribution by age groups in males and females

MALES							
	A	**B**	**C**	**D**	**E**	**F**	**Total (A-F)**
	13-19	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**13-69**
	(n=193)	**(n=466)**	**(n=414)**	**(n=186)**	**(n=100)**	**(n=26)**	**(n=1,385)**
Ethnic group							
Malay	59	191	213	97	50	12	622
Chinese	92	168	104	47	18	6	435
Indian	40	98	91	41	30	13	313
Others	2	9	6	1	2	1	21
Age (years)	16.7±0.1	24.1±0.1	34.2±0.1	44.2±0.2	52.3±0.2	63.2±0.6	31.6±0.3
Height (cm)	167.6±0.5	168.7±0.3	166.2±0.4	166.1±0.5	164.0±0.7	163.0±1.4	167.0±0.2
Weight (kg)	56.5±0.6	61.0±0.4	65.6±0.5	66.0±0.8	66.3±1.2	66.7±2.4	62.9±0.3

FEMALES							
	A	**B**	**C**	**D**	**E**	**F**	**Total (A-F)**
	13-19	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**13-69**
	(n=97)	**(n=325)**	**(n=121)**	**(n=40)**	**(n=24)**	**(n=7)**	**(n=614)**
Ethnic group							
Malay	32	146	45	19	11	3	256
Chinese	59	151	59	6	4	2	279
Indian	5	25	16	14	8	2	72
Others	1	3	1	1	1	-	7
Age (years)	17.1±0.2	23.6±0.2	33.8±0.2	45.0±0.5	52.7±0.5	63.1±1.3	27.6±0.4
Height (cm)	157.4±0.7	156.4±0.4	155.3±0.5	153.6±0.8	153.2±o.9	150.1±2.5	155.9±0.3
Weight (kg)	48.9±0.7	50.4±0.4	54.7±0.8	55.8±1.5	62.8±2.9	53.6±3.2	51.9±0.4

Zero-order correlation coefficients between the various anthropometric and lung function parameters were also carried out. FVC was significantly ($p<0.001$) correlated with age (male: r=-0.51; female: r=-0.48) and height (male: r=0.50; female: r=0.46). Similarly, FEV_1 also correlated significantly ($p<0.001$) with age (male: r=-0.58; female: r=-0.53) and height (male: 0.48; female: 0.45). FEV%, however, showed a significant ($p<0.001$) but weak negative correlation with age only (male: r=-0.25; female: r=-0.25).

Stepwise multiple regression for ages above 20 years was also used in determining the 'best' subsets of the anthropometric variables for the prediction of lung function parameters in Malaysian subjects. In calculating the equations for the regression of lung function with age, a curvelinear regression based on the natural log (log_e) could be used for both sexes. Since the use of these equations would become very cumbersome in daily clinical routines, the data was divided into 2 parts, one comprising the ages 13 to19 years and the other above 20 years of age. This is done because between the ages of 13 to 19 years, lung volumes are little influenced by age but markedly influenced by changes in body build and height associated with the growth spurt. Separate reference equations were derived using linear regression analysis for the younger age group and the adult age group and

Table II
Mean values and standard error of mean for lung parameters by age groups in males and females

	A	B	C	D	E	F	Total (A-F)
MALES							
	13-19	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**13-69**
	(n=193)	**(n=466)**	**(n=414)**	**(n=186)**	**(n=100)**	**(n=26)**	**(n=1,385)**
FEV_1	3.50	3.43	2.99	2.70	2.33	2.10	3.11
	±0.04	±0.03	±0.02	±0.04	±0.06	±0.10	±0.02
FVC	3.76	3.81	3.42	3.13	2.76	2.39	3.49
	±0.05	±0.03	±0.02	±0.04	±0.06	±0.10	±0.02
FEV%	93.30	90.22	87.6	86.4	84.9	87.7	88.9
	±0.5	±0.3	±0.3	±0.6	±0.8	±1.1	±0.3
FEMALES							
	A	**B**	**C**	**D**	**E**	**F**	**Total (A-F)**
	13-19	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**13-69**
	(n=97)	**(n=325)**	**(n=121)**	**(n=40)**	**(n=24)**	**(n=7)**	**(n=614)**
FEV_1	2.56	2.41	2.19	1.90	1.45	1.33	2.31
	±0.04	±0.02	±0.02	±0.08	±0.12	±0.06	±0.02
FVC	2.72	2.60	2.45	2.11	1.66	1.56	2.51
	±0.04	±0.02	±0.04	±0.09	±0.13	±0.10	±0.02
FEV%	94.2	92.4	89.7	90.3	88.1	86.0	91.8
	±0.7	±0.4	±0.6	±1.1	±1.7	±1.1	±0.3

are therefore tabulated in Table III for both sexes. Nomograms to facilitate the calculation of predicted values of FVC and FEV_1 from age and standing height of both the sexes are given in Figs 1 and 2.

Discussion

The purpose of this study was to determine lung function parameters with the aim of establishing population norms for Malaysians, covering most racial and socioeconomic groups. Population sample was drawn from residents living on and around the island of Penang. It is by far the largest single sample studied to date in Malaysia.

All the respiratory parameters measured were generally higher in males than in females (Tables I & II). Suffice to say that this is an expected observation in view of the larger anthropometry of the male.

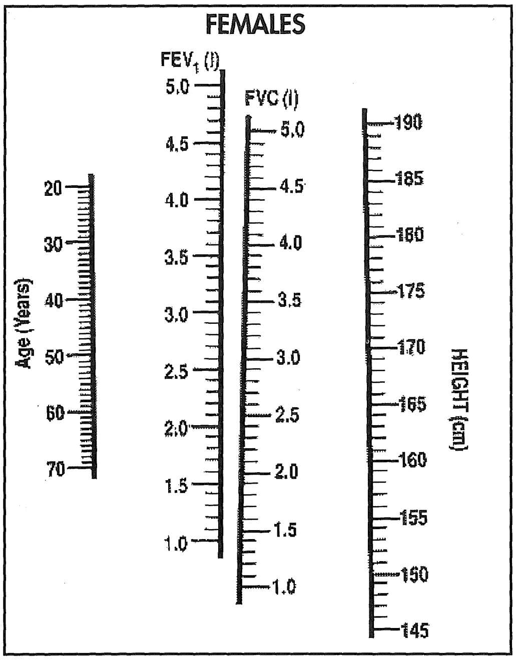
Analysis of lung function data shows that mean forced vital capacity of 3.49±0.02 L for a mean age of 31.6 years in the males (Tables I & II) in this study is similar to that observed in Indian[20] and Nepalese[21] males and in Pakistani workers in the United Kingdom[22], but is somewhat lower than that observed in age-matched European males[1,3,8]. In the females, mean FVC of 2.51±0.02 L for a mean age of 27.6 years (Tables I & II) is in good agreement with that observed in coastal New Guineans[23] but somewhat higher than that of the Indian women[20]. Again, it is lower than that in women from Europe[1,3,23,24]. The precise reason for the marked difference in FVC between Asians (Malaysians included) and Europeans is uncertain although it has been attributed to both genetic and environmental factors[25]. Anthropometric variations may explain some of these differences, as the physical build of Westerners on average is somewhat larger than that of Asians.

Lung functions in both the sexes appear to be lower with advancing age, particularly from the fourth decade of life onwards (Table II). Age-related decline in lung functions has been reported by a number of investigators[1,5,12]. Some age-related changes in the musculoskeletal system of the thoracic-abdominal compart-

Table III
Linear regression equations and residual standard deviations (RSD) for teenagers (13-19 years) and adults (20-69 years)

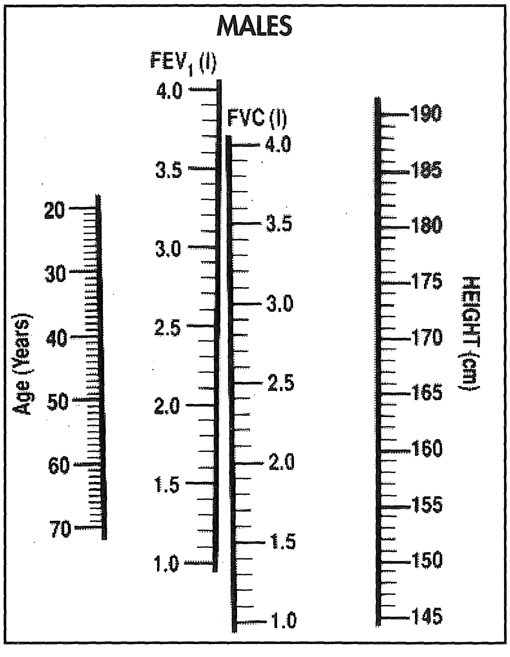
MALE	FEMALE
3-19 years	
FVC = 0.0504H + 0.0519A - 5.551	FVC = 0.0216H + 0.0162W - 0.891
RSD = 0.39; p<0.001	RSD = 0.28; p<0.001
FEV_1 = 0.0461H + 0.0579A - 5.191	FEV_1 = 0.0141H + 0.0194W - 0.605
RSD = 0.37; p<0.001	RSD =0.21; p<0.001
20-69 years	
FVC = 0.0407H - 0.0296A - 2.343	FVC = 0.0312H - 0.022A - 1.64
RSD = 0.44; p<0.001	RSD = 0.37; p<0.001
FEV_1 = 0.0353H - 0.0315A - 1.784	FEV_1 = 0.0294H - 0.0238A - 1.609
RSD = 0.48; P<0.001	RSD = 0.41; P<0.001

H=Height (cm); A=Age (years); W=Weight (kg).



FVC = 0.0312H - 0.0220A - 1.64
FEV_1 = 0.0294H - 0.0238A - 1.609
H = height in cms; A = age in years.

Fig 1:
Nomograms for prediction of FVC and FEV_1 from age and standing height for an adult Malaysian male.



FVC = 0.0407H - 0.0296A - 2.343
FEV_1 = 0.0353H - 0.0315A - 1.784
H = height in cms; A = age in years.

Fig 2:
Nomograms for prediction of FVC and FEV_1 from age and standing height for an adult Malaysian female.

ments have been considered to contribute to this decline. In this context, age-related decrease in maximal respiratory pressures has been reported in both the males and females, particularly in those over 55 years of age[26]. Interestingly, a study on cardiopulmonary functions during exercise on the same population also revealed a significant age-related decline in maximum oxygen consumption (VO_{2max}) in the males[27].

Regression analysis revealed that the rate of decline in FVC with age in our male subjects from 20 to 69 years is about 30 ml per year (Table III). This is higher than values of between 14 to 26 ml per year reported by others[1,4-6,11,12,29] but lower than that reported by Malik *et al*, 1972[22]. In females, the rate of decline is 22 ml per year. This is somewhat similar to what has been reported in other cross-sectional studies[1,29]. Rates of decline higher[4,25] and lower[6,11-13] than 22 ml per year, however, have also been reported in the females. The exact reason for these differences is unclear, although it has to be added that the present sample is the largest one studied in this region, covering a wide age range and representing a cross-section of a population of different ages and must therefore be a more accurate indicator of age-associated change in FVC.

Variations in both FVC and FEV_1 within a population varying in age from 13 to 69 years can also be described by a single curvilinear equation. However, in view of the rapid change in physical stature between the ages of 13 to 19, we have derived separate prediction formulae for individuals between the ages of 13 to 19 and those above 20 years of age (Table III).

Comparisons of observed mean FVC values between the ages of 20 to 69 years in this study with values predicted (for a 34 year old male measuring 167 cm in height or for a 28 year old female measuring 156 cm in height) using age and height standardised equations from data of different populations revealed consistently higher predicted values (Tables IVa & IVb). The predicted values were 1% to 50% greater than the observed means in the present study, except for 1 study[13], which showed a lower predicted value for the female. Similarly, the predicted values for FEV_1 were 3% to 47% greater than the observed mean in the present study except for 1 study in the male and female[13], which showed a lower predicted value. The biggest differences were found using formulae based on data of Europeans and Americans[1,4-6,24]. It is interesting to note that although the formulae were correlated for age and height, the predicted values for a given age and height were higher than the observed mean in our study. This is in contrast to the observations of Chan and Raman[14], who, in their report based on a small group of Malaysians, found no difference between their observed mean and that predicted using formulae from Western populations. The reason for the discrepancy between the study of Chan and Raman[14] and this study is not immediately apparent, although it could be methodological. More importantly, however, this observation reemphasises the need to be cautious when applying formulae derived from one population to another. Besides, it further reinforces the need for population groups to form their own population norms for the various physiological parameters.

In conclusion, this study shows that not only FVC but also FEV_1 is lower in Malaysians as compared to their contemporaries from Europe and America. Similar trends have also been seen in Indian, Chinese and African subjects[7,10-13]. This difference is present even when the effects of variation in age, height and weight are eliminated. It is unlikely that this is due to poor nutrition or health as all the subjects in this study were adequately nourished and healthy. Genetic, racial and environmental factors could possibly influence these parameters[25]. The difference notwithstanding, this study provides useful norms based on a large sample derived from the local population for clinicians in this region. In addition, it appears that for purposes of predicting lung functions for an individual it is always better to use equations derived from the same race or population sample.

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Table IVa

Comparison of predicted values using regression equations, for males with residual standard deviation (RSD) from other studies with the observed mean in the present study for a male 167 cm in height (H), 34 years of age (A)

Ref	n	FVC=	RSD	Predicted mean	Observed mean	Difference between means	% difference
Berglund *et al*[1]	296	0.048H-0.020A-2.21	0.50	5.13	3.42	1.71	50
Oxhøj *et al*[4]	240	0.062H-0.026A-4.60	0.52	4.87	3.42	1.45	42
Kory *et al*[5]	468	0.052H-0.022A-3.60	0.58	4.34	3.42	0.92	27
Cherniack & Raber[6]	870	0.048H-0.014A-3.18	-	4.36	3.42	0.94	27
Jain & Ramiah[9]	188	0.044H-3.313	0.49	4.04	3.42	0.62	18
Chuan & Chia[11]	50	0.048H-0.0156A-3.80	0.38	3.68	3.42	0.26	97
Da Costa[12]	134	0.0409H-0.0105A-2.761	0.55	3.71	3.42	0.29	8
Johannsen & Erasmus[13]	120	0.0375H-2.835	0.45	3.43	3.42	0.01	-
Malik *et al*[22]	371	0.066H-0.034A-5.98	-	3.89	3.42	0.47	13
Miller *et al*[28]	96	0.044H-0.024A-2.90	0.46	3.63	3.42	0.21	6
Present study	1192	0.0407H-0.0296A-2.343	0.44	3.44	3.42	0.02	-

Table IVb
Comparison of predicted values using regression equation, for females with residual standard deviation (RSD), from other studies with the observed mean in the present study for a female 156 cm in height (H), 28 years of age (A)

Ref	n	FVC=	RSD	Predicted mean	Observed mean	Difference between means	% difference
Berglund *et al*[1]	201	0.040H-0.022A-2.351	0.40	3.27	2.60	0.67	26
Oxhøj *et al*[4]	277	0.043H-0.027A-2.10	0.52	3.85	2.60	1.19	48
Cherniack & Raber[6]	452	0.031H-0.015A-1.05	-	3.37	2.60	0.77	30
Chuan & Chia[11]	51	0.025H-0.0034A-1.17	0.33	2.63	2.60	0.03	1
Da Costa[12]	73	0.0182H-0.0147A +0.0134W-0.289	0.37	2.83	2.60	0.23	9
Johannsen & Erasmus[13]	100	0.023H-0.014A-0.662	0.54	2.53	2.60	-0.07	-3
Hall *et al*[24]	141	0.047H-0.029A-2.88	0.44	3.64	2.60	1.04	40
Miller *et al*[28]	109	0.0315H-0.020A-1.55	0.38	2.80	2.60	0.20	8
Present study	517	0.0312H-0.022A-1.64	0.37	2.61	2.60	0.01	-

W=weight (kg)

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