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Forced expiratory indices in normal Libyan children aged 6–19 years

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ABSTRACT Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were measured in 796 Libyan children (386 boys and 410 girls) with ages ranging from 6 to 19 years. Values in girls were significantly less than those in boys after allowance had been made for age and height. FVC and FEV_1 correlated best with standing height but were also correlated with body weight. These results may be used as a source of standard values for Libyan children.

Introduction

Pulmonary function studies have been carried out on various populations to establish reference values and formulae from which normal values can be predicted according to age, sex, and standing height. These reference or normal values of respiratory function, which have been shown to depend on the ethnic and racial origin of the population, are used to identify abnormal values and hence the nature and the degree of functional abnormality.

The aim of this study was to present reference values of forced expiratory indices for Libyan children as these have not been described previously.

Methods

We selected non-smoking, healthy Libyan schoolchildren from various schools at Benghazi on the Mediterranean coast. We excluded children with a history of respiratory disease and rejected 55 children because they were unable to perform spirometric tests adequately. All the children were of the same ethnic origin and there was little variation in socioeconomic conditions in the population studied.

Forced expirations were measured with an expired gas bellows spirometer (Vitalograph Inc), with the subject standing and wearing a noseclip. Only the recordings that satisfied the criteria of Segall and Butterworth[1] for maximal mid expiratory flow time were considered, and the highest of three measurements was selected. The following measurements were obtained from the tracing: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced expiratory ratio (FEV_1/FVC × 100), forced expiratory flow between the first 200 and 1200 ml of the FVC ($FEF_{200-1200}$), and forced mid expiratory flow between 25% and 75% of the FVC (FMF). All volumes were converted to body temperature and pressure saturated volumes (BTPS). The same equipment and observer were used for all subjects and the recordings were made between 8.00 am and 1.00 pm over eight months. The mean (SD) ambient temperature in the thermostatically controlled laboratory was 20°C (1°C).

Age was calculated to the nearest 6 months from the birth certificates (table 1). Standing height was measured to 0·1 cm with a portable stadiometer (Holtain Ltd) and body weight to 0·1 kg with portable field survey scales (CMS Weighing Equipment Ltd).

DATA ANALYSIS

The data were initially plotted graphically on box plots and scatter plots with percentile curves estimated by linear regression. Correlation coefficients were calculated for the various physical and lung function measurements. Multiple regression analysis was used to assess the simultaneous effects of age, height, weight, and sex on log transformed lung function measures. Other models were tried by progressively extending the number of variables to include: (*a*) all four explanatory variables; (*b*) interaction terms between sex and height, age, and weight, to allow for the possibility that these three covariates might differ in their effect between boys and girls; (*c*) separate height terms for children above and below 13 years, to allow for possible changes in the influence of height on lung function in children of different ages. Calculations

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Table 1 *Age distribution of the children in the study*

Age (y)	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*
Boys (n)	30	26	22	21	19	22	37	28	20	31	41	32	28	29
Girls (n)	23	25	28	27	23	25	23	23	22	26	39	44	52	30

were performed with the Statgraphics computer program[2] and GLIM.[3]

Results

The correlation coefficients between physical and lung function measurements are shown in table 2. FEV_1 and FVC were highly correlated with each other and both were highly correlated with age, standing height, and body weight. FEF and FMF showed moderate correlations with these variables whereas FEV_1% VC was independent.

Table 3 shows the values of the coefficient of determination (R^2) obtained with several simple and multiple regression models. Of the explanatory variables investigated, height showed the strongest correlations with all the lung function indices. Sex differences were small in relation to the variation explained by height. After age and height have been allowed for, the difference between boys and girls was still evident. Inclusion of age as an additional variable in the multiple regression equations after height and sex had been fitted gave a further small increase in the coefficient of determination.

The more complicated models (i–iii under "Data analysis" above) did not change the coefficients of determination appreciably. A simple regression model using height as the predictor variable appears to give a reasonable description of the observed data for most of the measures. Figures 1 and 2 show selected estimated percentile curves based on height only. For every centimetre increase in standing height FVC increased 2·17% in boys and 2·42% in girls. FEV_1 on the other hand increased 2·28% and 2·41% in boys and girls respectively. A slightly improved prediction is possible for most of the indices if age is also included in the multiple regression equation. Table 4 shows the coefficients resulting from multiple regression of log lung function on height, age, and sex. For example, predicted log FVC = − 1·781 + 0·0148(HT) + 0·0405(AGE) − 0·157 (if SEX = female). The FEF and FMF data as well as enlarged versions of figures 1 and 2 are available from the authors.

Lung function values increased progressively with age in boys and girls. Being dependent on body size, they levelled off in girls at the age of 15 years and in boys at the age of 18 years.

Table 2 *Correlation matrix of physical and lung function measures for boys and girls*

	Age	*Weight*	*Height*	*FVC*	*FEV_1*	*FEF*	*FMF*
Age	1	0·818	0·925	0·906	0·896	0·630	0·735
		0·824	0·877	0·837	0·823	0·525	0·658
Weight		1	0·876	0·880	0·860	0·550	0·690
			0·844	0·836	0·816	0·473	0·602
Height			1	0·924	0·912	0·612	0·740
				0·881	0·862	0·542	0·670
FVC				1	0·978	0·650	0·772
					0·945	0·590	0·702
FEV_1					1	0·685	0·816
						0·734	0·827
FEF						1	0·644
							0·731

FVC—forced vital capacity; FEV_1—forced expiratory volume in one second; FEF—forced expiratory flow; FMF—forced mid expiratory flow.

Discussion

The changes in lung function indices with age and the pattern of correlations found among our variables were broadly similar to those found by Dickman *et al* in American children,[4] by Sliman *et al* in Jordanian children,[5] and by Deshpande *et al* in Indian children.[6]

The Libyan children in our study had FVC and FEV_1 values about 20% lower than the values predicted from the regression equations derived from Jordanian children. This may be due to the effect of

Table 3 *Coefficients of determination (R^2) obtained in multiple regression analysis (percentages)*

Explanatory variables	*Dependent variable (log transformed)*			
	FVC	*FEV_1*	*FEF*	*FMF*
Age	72·5	72·2	44·0	51·7
HT	80·6	79·0	50·9	54·8
WT	65·1	63·5	36·1	43·7
Sex	2·9	2·6	2·1	1·1
Sex, age	78·1	77·2	49·8	54·2
Sex, height	82·0	80·2	52·2	55·1
Sex, weight	68·5	66·9	39·2	44·9
Sex, height, age, weight	82·7	80·9	52·5	55·4
Sex, height, age	84·7	83·2	55·3	57·7
Sex, weight, age	81·0	79·8	51·5	55·5
Sex, height, weight	84·9	83·4	55·3	57·8
Sex* (height, age, weight)	85·3	83·8	56·2	58·3
Sex, height, age, weight, HtA†	84·9	83·4	55·3	58·0

*Fits separate height, age, weight terms for each sex.
†Fits sex, height, age, weight plus a separate height term for age > 13 years (HtA).
Abbreviations as in table 2.

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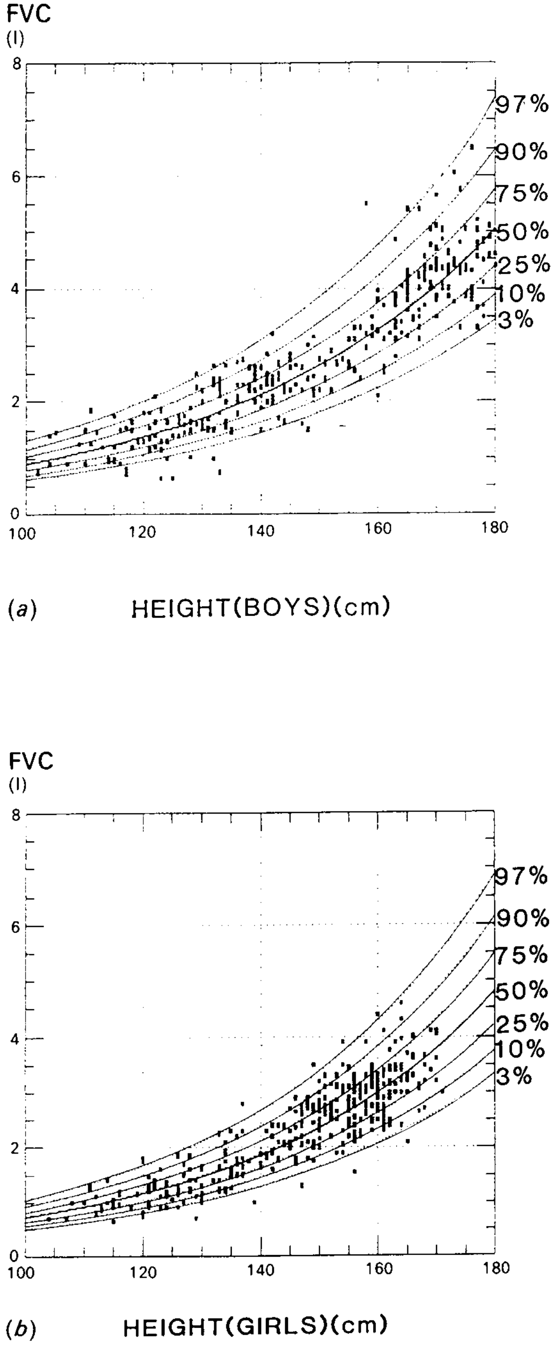

Fig 1 *Percentile curves of forced vital capacity (FVC) plotted against standing height (Ht, cm): (a) boys (log FVC = 0·021Ht–2·257, r = 0·919, SEE = 0·00052); (b) girls (log FVC = 0·023Ht–2·693, r = 0·894, SEE = 0·00064).*

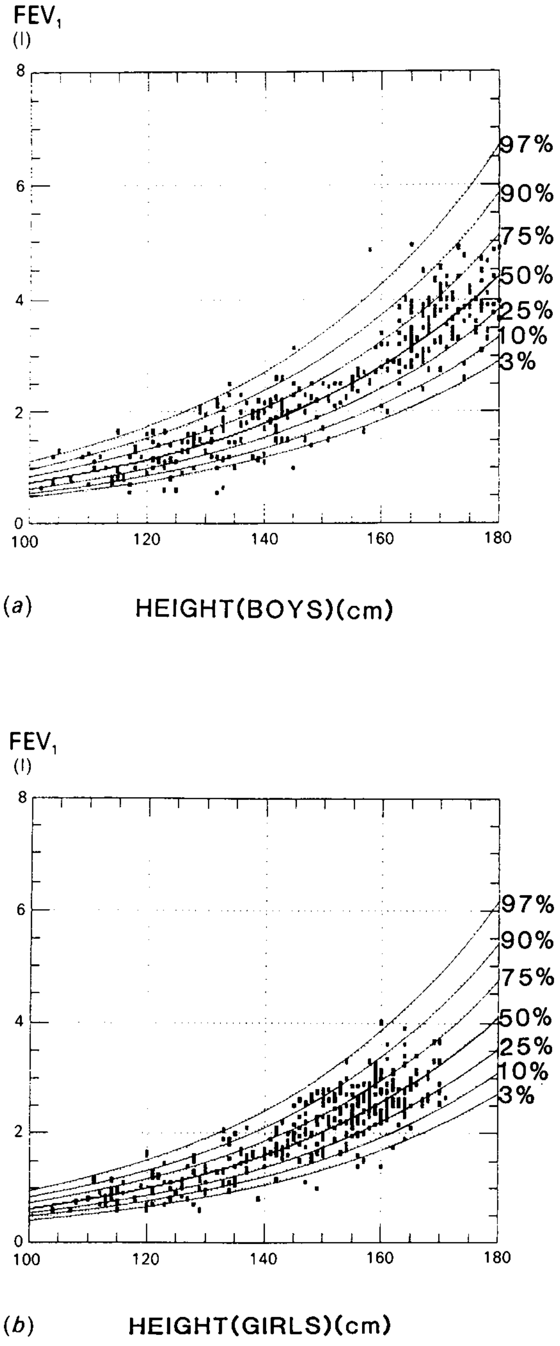

Fig 2 *Percentile curves of one second expiratory volume (FEV_1) plotted against standing height (Ht, cm): (a) boys (log FEV_1 = 0·022Ht–2·567, r = 0·910, SEE = 0·00058); (b) girls (log FEV_1 = 0·023Ht–2·810, r = 0·872, SEE = 0·00074).*

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Table 4 *Multiple regression coefficients in equations using height, age, and sex as explanatory variables*

		Independent variables			
Dependent variable	*Constant*	*Height (cm)*	*Age (y)*	*Sex (M = 0, F = 1)*	*Sy.x*
FVC	−1·781	0·0148***	0·0405***	−0·157***	0·181
FEV_1	−1·961	0·0146***	0·0449***	−0·153***	0·201
FEF	−2·280	0·0185***	0·0513***	−0·218***	0·431
FMF	−1·803	0·0150***	0·0382***	−0·115***	0·380

***$p < 0·001$.
Abbreviations as in table 2.

altitude since the Jordanian children were from Amman (774 metres above sea level) and the Libyan children were living at sea level. The rate of increase in FVC with height in adolescent Libyan boys was almost the same as that found in adolescent American boys studied by Dickman (90 ml/cm standing height)[4] yet the rate in adolescent Libyan girls (45 ml/cm) was less than that found in adolescent American girls (58·6 ml/cm). Weight played a smaller part in determining lung function than in the Jordanian study,[5] most of the variation in our data being explicable by age, sex and height. Adding body mass index (weight divided by height squared) instead of weight to our multiple regression equation made no difference to the coefficient of determination. Some studies[5 7] have used logarithmic transformations of some of the explanatory variables (height, age) but this did not improve the fit in our study.

We did not record the pubertal status of the children so our results are useful for cross sectional rather than longitudinal comparisons. More detailed account of age, particularly during adolescence, would have to be taken to make longitudinal predictions.

There were few girls over 170 cm in height and few of either sex less than 110 cm, so the percentile graphs in these ranges (figs 1 and 2) can not be regarded as reliable.

Our results provide a source of standard values for forced expiratory indices for Libyan children. We have no reason to believe that Benghazi children differ from Libyan children in other parts of the country. Studies in other areas would, however, be useful to show whether they are representative of Libyan schoolchildren generally.

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