Forced expiratory indices in normal black Southern African children aged 6–19 years

M H Shamssain

Abstract

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced expiratory ratio ($FEV_1/FVC \times 100$), forced mid expiratory flow (FMF), and peak expiratory flow (PEF) were measured in 2000 non-smoking black African schoolchildren aged 6–19 years from Umtata in the Republic of Transkei in Southern Africa. FVC, FEV_1, FMF, and PEF were highly correlated with each other and all were highly correlated with age and standing height in both sexes. There was a significant negative correlation between FEV_1/FVC and both age and standing height. An increase in the slope of the increase in FVC for both age and height occurred at 11 years and 143 cm in girls and at 13 years and 150 cm in boys. This continued for about two years and 10 cm in both groups before it declined. The mean values of FEV_1, FEV_1/FVC, and PEF in the present study were 14% lower than those obtained in black American schoolchildren. The present study is the largest study of urban black African schoolchildren and provides useful reference values.

Pulmonary function studies have been carried out in 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 degree of functional abnormality.

The aim of this study was to obtain reference values of pulmonary function for normal black schoolchildren from the Republic of Transkei in Southern Africa as these have not been reported previously. This is the largest study of pulmonary function in urban black schoolchildren to be reported.

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Methods

Two thousand non-smoking, healthy black schoolchildren aged 6–19 years from various schools in Umtata, Republic of Transkei, were included in this study by the cluster sampling method. The Republic of Transkei is a small state in Southern Africa on the Indian Ocean with a population of 4·0 millions (latitude 31° 19′S, longitude 28° 39′E). All the children were black and from the Xhosa tribe (total population in Southern Africa 10 millions) and of the same socioeconomic status. A questionnaire from the British Medical Research Council was modified for this population. A local Xhosa speaking interviewer helped in filling in the questionnaires. All children with a history of respiratory disease were excluded from the study and 48 children were rejected because they were unable to perform spirometric tests adequately.

MEASUREMENTS

Forced expiratory indices were determined with an expired gas bellows spirometer (Vitalograph), with the subject standing and wearing a nose clip. The spirometer was calibrated with a 1 litre precision syringe (Vitalograph). The best of three attempts was selected. The best curve was that which produced the highest forced expiratory volume in one second (FEV_1), provided that the forced vital capacity (FVC) was close to the subject's best FVC. The following measurements were obtained from the spirometer: FVC, FEV_1, forced expiratory ratio ($FEV_1/FVC \times 100$), forced mid expiratory flow between 25% and 75% of FVC (FMF), and peak expiratory flow (PEF). All volumes were converted to body temperature and pressure saturated (BTPS). The same equipment and observer were used for all subjects and the recordings were made between 8.00 and 13.00 hours over nine months. The mean (SD) ambient temperature was 18° (2°) C.

Age was calculated to the nearest six months from school records (table 1). Stand-

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)	64	64	61	61	74	66	73	75	60	71.	75	70	83	76
Girls (n)	57	72	67	66	67	75	80	72	65	75	84	76	86	84

Table 2 Multiple regression coefficients in equations using height and age as explanatory variables (standard errors in parentheses)

			Independent variables		
Dependent variables	*Sex*	*Constant*	*Height (cm)*	*Age (y)*	R^2
FVC (l)	M	−3·744***	0·031***	0·138***	0·764
		(0·264)	(0·003)	(0·013)	
	F	−2·855***	0·026***	0·110***	0·723
		(0·223)	(0·002)	(0·009)	
FEV_1 (l)	M	−2·705***	0·023***	0·107***	0·742
		(0·214)	(0·002)	(0·011)	
	F	−1·807***	0·018***	0·088***	0·681
		(0·183)	(0·002)	(0·008)	
FEV_1%	M	101·246***	−0·104**	−0·352*	0·097
		(4·323)	(0·044)	(0·213)	
	F	108·794***	−0·152***	−0·391*	0·119
		(4·652)	(0·045)	(0·196)	
FMF (l/s)	M	−1·795***	−0·009	0·219***	0·405
		(0·534)	(0·005)	(0·026)	
	F	0·083	−0·002	0·188***	0·334
		(0·431)	(0·004)	(0·018)	
PEF (l/s)	M	−4·195***	0·036***	0·262***	0·504
		(0·714)	(0·007)	(0·035)	
	F	−0·868	0·006	0·295***	0·437
		(0·612)	(0·005)	(0·026)	

*$p < 0·05$; **$p < 0·01$; ***$p < 0·001$.

FVC—forced vital capacity; FEV_1—forced expiratory volume in one second; FEV_1%—forced expiratory ratio; FMF—forced mid expiratory flow between 25% and 75% of FVC; PEF—peak expiratory flow; R^2—proportion of the variability in the data explained by the fitted model.

ing height was measured to 0·1 cm with a portable stadiometer and body weight to 0·1 kg with portable field survey scales according to the recommendations of the International Biological Programme.[1]

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 lung function measures. Calculations were performed with the Statgraphic computer program.[2]

Results

The age distribution of the children is shown in table 1 and the multiple regression coefficients for the equations using height and age as explanatory variables in table 2. This allows prediction of pulmonary function according to height, age, and sex. For example, predicted FVC in boys =

$$-3·744 + 0·031\,(\text{HEIGHT}) + 0·138\,(\text{AGE}).$$

FVC, FEV_1, FMF, and PEF were highly correlated with each other and all were highly correlated with age and standing height in both sexes. FVC and FEV_1 values for boys and girls of different heights are given in table 3. There was a significant negative correlation between FEV_1/FVC and both age and height. After age and height have been allowed for, a difference in lung function indices between boys and girls was still evident. The effect of weight was not significant.*

Discussion

Previous studies of black children have included 521 girls and 501 boys from the United States (Schoenberg *et al*[3]), 1041 black children, also from the United States, (Dockery *et al*[4]), 161 boys and 144 girls from Africa (Miller *et al*[5]), and 97 children from Upper Volta (Huizinga and Glanville[6]). Thus our report presents the largest study of urban black schoolchildren.

Although body weight correlates significantly with lung function measurements, body weight and age are strongly related and when standing height, age, and body weight were included in the regression analysis the coefficient for body weight was not significant.

Lung function values increased progressively with increasing age in boys and girls. Being dependent on body size, they levelled off in girls at the age of 17 years and in boys at the age of 18 years. Among girls there was an increase in the slope of the FVC/age line at 11 years, which continued for two years. A similar increase was seen in the slope of the FVC/height line, starting at 143 cm and continuing for 10 cm. FVC continued to increase up to 17 years. Among boys this acceleration started at 13 years and at 150 cm and continued for similar periods. FVC continued to increase up to 18 years. These findings are related to the growth spurt seen in this population[7]: the adolescent growth spurt starts in girls at around 11 years but in boys at around 13 years. The mean duration of the pubertal period in our study was two years for both boys and girls.[7] After the age of 6 years the peak height velocity was 7·7 cm/y in boys and 7·9 cm/y in girls.

Carson *et al*[8] found an increase in the slope of the PEF/age line at 12 years among Irish girls and this continued for two years. A similar increase was seen in the slope of the PEF/height line, starting at 145 cm and continuing for 15 cm. Among Irish boys this change started at 14 years and at 155 cm and continued for similar periods. An acceleration of lung function growth in relation to height with the onset of puberty was seen in the study by Dickman and associates.[9] They suggested that this change occurred at a height of about 152·4 cm.

Dockery *et al*[4] found that black children in

*Further data may be obtained from the author.

Table 3 Mean values forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) in boys and girls

Height (cm):		120	122	124	126	128	130	132	134	136	138	140	142	144	146
FVC (l)	M	1·19	1·21	1·28	1·37	1·43	1·50	1·65	1·72	1·80	1·86	2·00	2·07	2·09	2·30
	F	1·17	1·20	1·24	1·29	1·35	1·45	1·53	1·69	1·75	1·80	1·82	2·00	2·05	2·25
FEV_1 (l)	M	1·02	1·16	1·20	1·25	1·31	1·36	1·58	1·60	1·66	1·69	1·79	1·81	1·90	1·93
	F	1·00	1·10	1·18	1·15	1·28	1·30	1·40	1·48	1·51	1·58	1·63	1·77	1·85	1·90

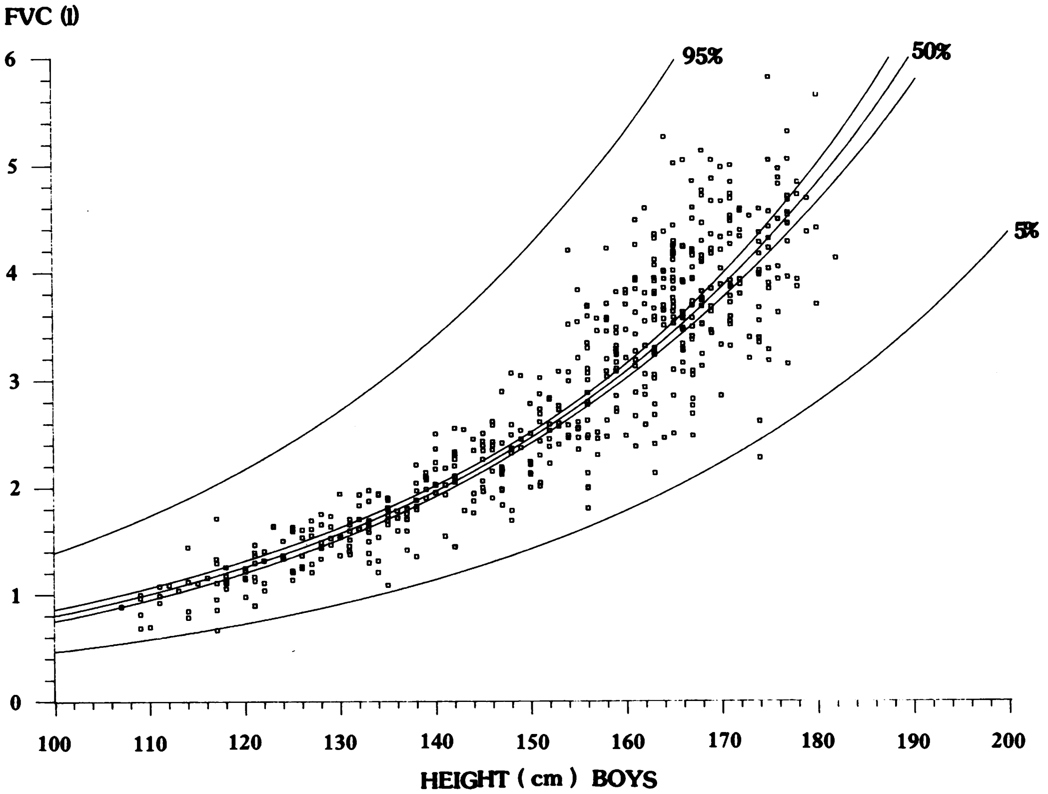

Figure 1 Percentile curves of forced vital capacity (FVC) plotted against standing height in boys (FVC = 0·022 Ht − 2·469, r = 0·808, SEE = 0·00061). The inner lines indicate the standard error of the mean of FVC.

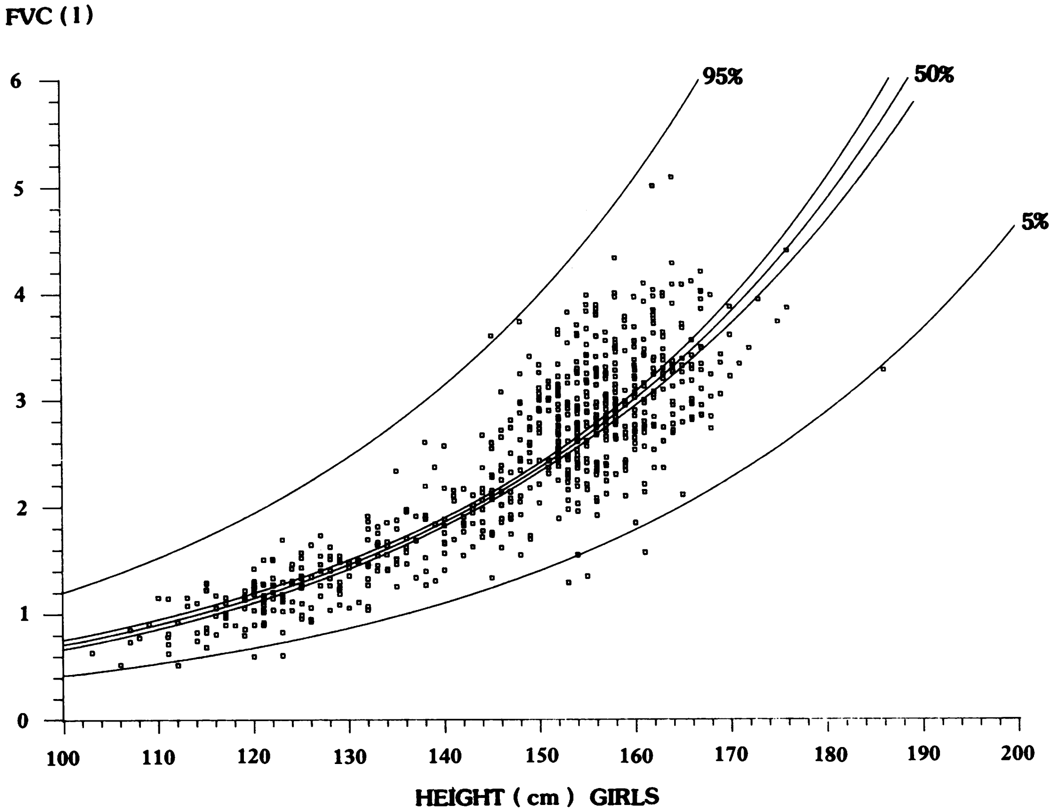

Figure 2 Percentile curves of forced vital capacity (FVC) plotted against standing height in girls (FVC = 0·024 Ht − 2·747, r = 0·796, SEE = 0·00061). The inner lines indicate the standard error of the mean of FVC.

148	*150*	*152*	*154*	*156*	*158*	*160*	*162*	*164*	*166*	*168*	*170*	*172*	*174*	*176*	*178*
2·38	2·44	2·52	2·91	3·02	3·17	3·40	3·49	3·75	3·86	3·89	3·91	4·03	4·27	4·32	4·50
2·33	2·38	2·48	2·83	2·93	3·10	3·15	3·16	3·34	3·36	3·43					
2·00	2·05	2·14	2·32	2·39	2·51	2·73	2·84	3·04	2·89	2·95	2·97	3·28	3·19	3·40	3·41
1·97	2·00	2·10	2·23	2·30	2·35	2·40	2·42	2·48	2·58	2·64					

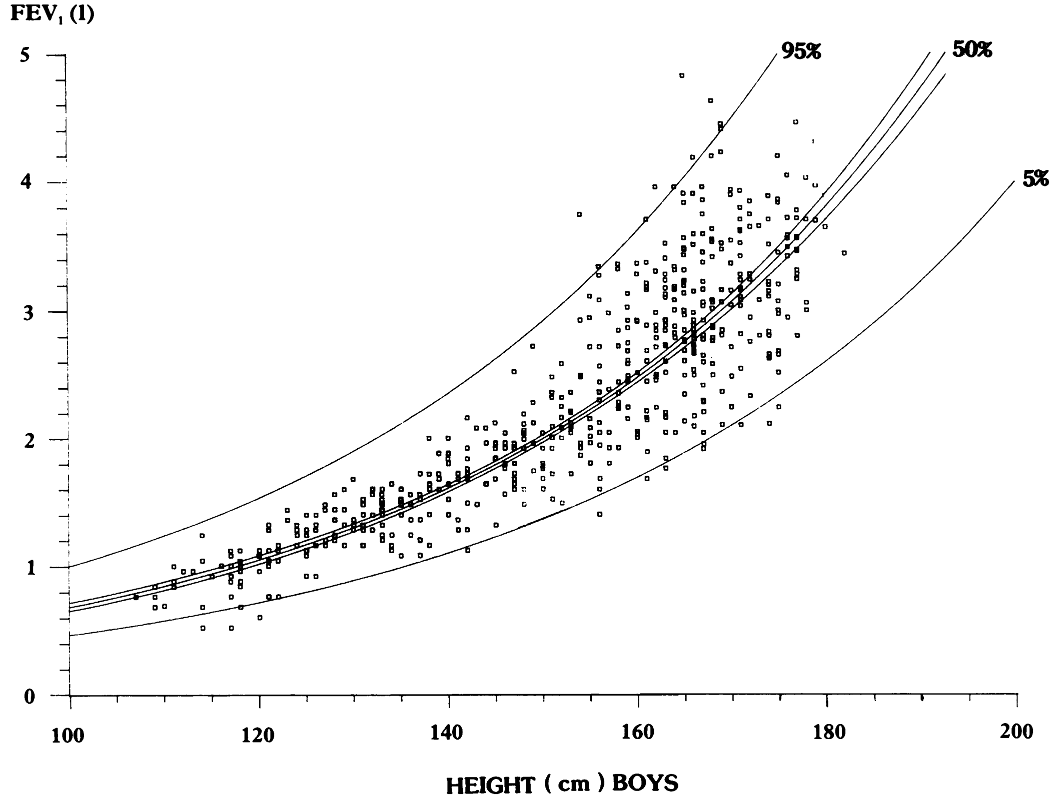

Figure 3 Percentile curves of forced expiratory volume in one second (FEV_1) plotted against standing height in boys ($FEV_1 = 0{\cdot}021\ Ht - 2{\cdot}524, r = 0{\cdot}884, SEE = 0{\cdot}00042$). The inner lines indicate the standard error of the mean of FEV_1.

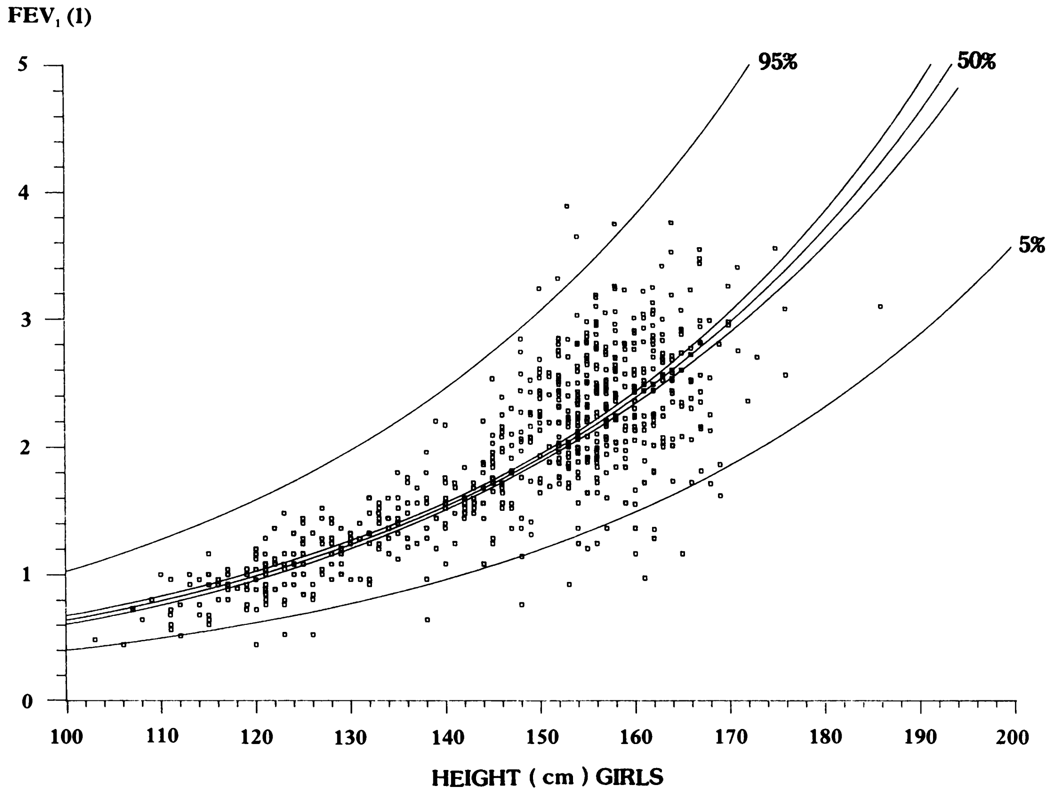

Figure 4 Percentile curves of forced expiratory volume in one second (FEV_1) plotted against standing height in girls ($FEV_1 = 0{\cdot}021\ Ht - 2{\cdot}641, r = 0{\cdot}801, SEE = 0{\cdot}00054$). The inner lines indicate the standard error of the mean of FEV_1.

the United States had median values of FVC and FEV_1 that were about 13% lower than those for white children of the same sex and standing height. There was no difference between black and white children in the FEV_1/FVC ratio for a given level of FVC.

A centile chart is the best method of presenting normal values for height and weight, and the same method may reasonably be used for lung function data. Percentile charts of FVC and FEV_1 plotted against height can be applied easily by respiratory physicians to assess the lung function of children. Our lung function growth charts have the advantage of being derived from a large data base, uniformly collected with exactly the same equipment and criteria for inclusion. The plotted curves can be used directly, or the regression equations can be used to obtain predicted values. There were few boys over 180 cm in height and few girls over 170 cm, and there were few of either sex less than 110 cm; so the percentile graphs in these ranges (figs 1–4) cannot be regarded as reliable.

The lung function values for the children in this study were compared with those for black children elsewhere. The rate of increase in FVC with standing height in adolescent black African boys and girls was similar to that seen in adolescent Libyan boys and girls (90 and 45 ml/cm) in our previous study.[10] The FVC values for the two populations were similar for the same height and sex. Mean values of FEV_1, FEV_1/FVC, and PEF were, however, around 14% higher in black American children studied by Schoenberg *et al*[3] than in black African children in our study for the same height and sex. Black American children were also taller than the black Africans. Black African children in the present study had lower FVC, FEV_1, and PEF values (around 12·8% lower) and were shorter than African children studied by Miller *et al*[5] for the same age and sex, and they were also lower than the values seen in Afrocaribbean children living in Nottingham.[11] Predicted values of FVC, FEV_1, and FEV_1/FVC in the present study were, however, higher than the predicted values in children from Upper Volta studied by Huizinga and Glanville.[6] The PEF values obtained in the present study were lower than those seen in Ethiopian children studied by Teklu *et al*,[12] whereas FVC and FEV_1 were higher than those obtained in Ethiopian schoolchildren at Adi-Arkai (altitude 1500m)[13] and similar to the values obtained in schoolchildren at Debarech on the edge of the Simien plateau (altitude 3000 m). These differences in pulmonary function might be due to the way the measurements were made or to altitude.

The present results show that forced expiratory indices in black people in Africa are lower than in black people in the United States. The present results reflect lung function among healthy urban black African schoolchildren living in the Republic of Transkei and can be used as reference values for urban black Southern African schoolchildren.

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