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〔Original〕

Predictions of Normal Forced Vital Capacity and Forced Expired Volume in One Second in Tanzanian Children

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Abstract: Data on ventilatory function with particular reference to forced vital capacity (FVC), forced expired volume in one second (FEV_1), and FEV_1 expressed as percentage of FVC (FEV_1%FVC) were obtained in 1413 healthy Tanzanian school children aged between 8 and 18 years. All subjects were nonsmokers and had neither symptoms nor history of cardiopulmonary diseases. Subjects in this study were significantly smaller in stature ($P<0.05$) and had smaller FVC and FEV_1 ($P<0.001$) compared to values reported in children of comparable age and stature in the west. Lung volumes could best be described as a power function of standing height ($y=a.H^b$). The power derived from ln FVC on ln H were 3.39 and 3.24 for boys and girls respectively, while the power derived from ln FEV_1 on ln H were 3.11 and 3.03 for boys and girls respectively. Constructed prediction formulae gave FEV_1 and FVC which showed good agreement with FEV_1 and FVC computed from prediction equations based on a similar mathematical model for black children in the Caribbean.

Key words: forced vital capacity, forced expired volume in one second, forced expired volume in one second as a percentage of forced vital capacity.

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Introduction

Evidence in the literature shows that differences exist among races in some of the commonly used ventilatory measures of pulmonary function (Wall *et al.*, 1982; Strope & Helms, 1984). Values for Afro-Americans were reported to be lower than values in white Americans (Chehreh *et al.*, 1973; Schoenberg *et al.*, 1978; Hsu *et al.*, 1979), and Indians have been reported to have lower FEV_1 and FVC values than Afro and White Americans (Oscherwitz *et al.*, 1972).

Summary regression curves and prediction equations of ventilatory functions for Caucasian children have been compiled (Polgar & Promadhat, 1971; Quanjer, 1983), while similar studies in Tanzanian children are not available. Hence, screening for obstructive pulmonary diseases is still based on reference values derived from Caucasian populations. The present study is directed towards filling that gap by determining the nature of the forced vital capacity (FVC), one second forced expired volume (FEV_1) and FEV_1%FVC, and constructing prediction formulae from these data in normal Tanzanian school children in Dar es Salaam.

Subjects and Methods

The study reports results from 1413 (726 boys and 687 girls) healthy school children aged between 8 and 18 years. The subjects studied were volunteers who besides being nonsmokers had no symptoms of cardiopulmonary diseases as judged from answers to an elaborate Kiswahili translation of the MRC Questionnaire on Respiratory Symptoms (Mashalla, 1987), and clinical examination. The answers in relation to abnormal respiratory symptoms were negative in all subjects presented in this study.

The test was conducted by trained personnel who were thoroughly familiar with the instruments and the technique. Standing height was measured without shoes or in socks using a portable Holtain stadiometer which has a resolution of 1 mm. Spirometric measurements were performed in the standing position using a 7 litre dry wedge spirometer (Vitalograph, Birmingham, England). The subject to be tested was first made familiar with the instrument and testing technique. With a nose clip obstructing the nares the subject performed five satisfactory forced expiratory manoeuvres. All parameters reported herein were calculated from the test with the largest FVC and FEV_1. Regression analysis of pulmonary function results on standing height were performed based on a power function $y = a.H^b$ and the validity of the prediction formulae were assessed by comparing results in this study with results of equations based on a similar mathematical model (Hsu *et al.*, 1979) in children of African origin in the Caribbean. Volumes are expressed in ml BTPS and the paired t-test was used to examine differences between mean results.

Results

Anthropometric data and lung function results of all subjects are presented in Table 1. Before 14 years of age girls are on average taller than boys ($P < 0.05$). Thereafter, boys become increasingly tall so that at 16 years of age boys are significantly taller than girls ($P < 0.001$). Marked annual increment in standing height occurred between 11−13 years in girls, and between 12−14 years in the boys.

Relationship of FEV_1 and FVC with age for boys and girls are shown in Fig. 1. Marked annual increases in FEV_1 and FVC occurred between 11 − 14 years and 13 − 15 years in girls and boys respectively. The relationship of FEV_1%FVC with age is shown in Fig. 2. FEV_1%FVC shows a downward trend and on average FEV_1%FVC declined ($P > 0.3$) at 0.22% and 0.46% per year in girls and boys, respectively.

Comparison of subjects mean standing height between this study and Caucasian children is shown in Fig. 3. For the same age Tanzanian children have significantly smaller mean standing height ($P < 0.05$) than their white counterparts e.g. at 13 years mean standing heights of subjects in this study are 145.6 (SD 8.0) cm and 149.8 (SD 7.0) cm as compared to 155.5 (SD 8.7) cm and 157.5 (SD 5.9) cm in Caucasian boys and girls, respectively.

Table 1. Mean standing height (cm), FVC and FEV_1 (ml BTPS) and FEV_1%FVC for school boys and girls in Dar es Salaam

Sex	Age (years)	N	Stature	FVC (ml)	FEV_1 (ml)	FEV_1%FVC
Boys	8− 9.9	4	129.2 (5.6)	1476 (612)	1373 (635)	93.7 (5.1)
	10−10.9	25	135.2 (7.4)	1761 (242)	1584 (251)	90.1 (6.5)
	11−11.9	66	137.3 (7.2)	1754 (144)	1581 (143)	90.3 (5.4)
	12−12.9	100	142.1 (8.3)	1916 (119)	1717 (118)	89.7 (5.1)
	13−13.9	120	145.6 (8.0)	2070 (109)	1852 (107)	89.6 (5.4)
	14−14.9	100	150.4 (9.7)	2291 (125)	2035 (122)	89.1 (6.2)
	15−15.9	115	155.5 (8.7)	2547 (113)	2228 (114)	87.7 (6.3)
	16−16.9	97	160.8 (6.9)	2952 (123)	2580 (121)	86.7 (6.2)
	17−17.9	99	164.9 (7.4)	3337 (121)	2879 (121)	86.4 (5.8)
Girls	8− 9.9	13	132.8 (4.5)	1459 (338)	1345 (344)	92.3 (4.5)
	10−10.9	60	134.4 (5.8)	1561 (152)	1429 (153)	91.7 (4.7)
	11−11.9	90	139.6 (6.8)	1655 (125)	1501 (124)	90.8 (4.6)
	12−12.9	152	145.4 (6.9)	1860 (97)	1676 (97)	90.3 (5.6)
	13−13.9	144	149.8 (7.0)	2063 (98)	1846 (98)	89.7 (5.1)
	14−14.9	118	152.8 (6.3)	2216 (109)	1991 (110)	89.7 (6.5)
	15−15.9	81	154.2 (6.7)	2329 (135)	2095 (135)	90.1 (5.2)
	16−16.9	25	157.5 (5.9)	2562 (232)	2300 (230)	90.1 (5.8)
	17−17.9	4	153.8 (1.5)	2452 (642)	2085 (650)	85.1 (3.7)

In brackets are standard deviations (SD)

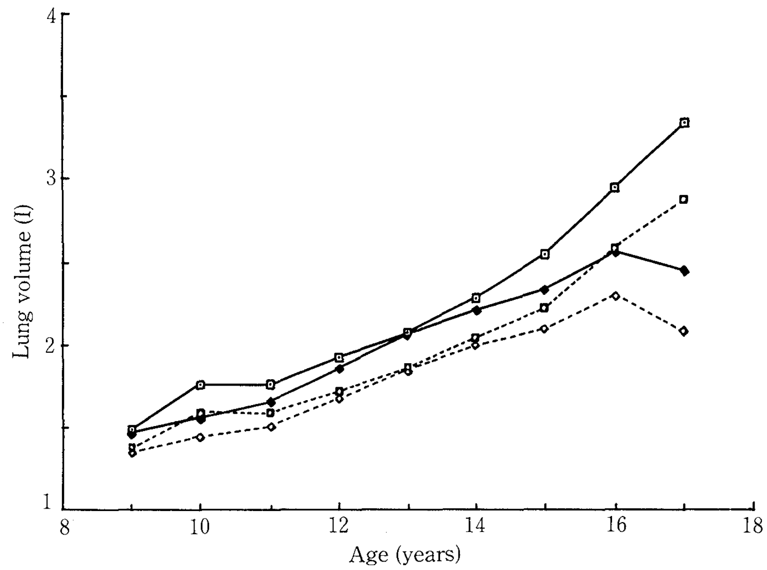

Fig. 1. Relationship of mean FVC and FEV_1 values (l) with age for Dar es Salaam school children.
□ FVC boys, ◘ FEV_1boys ◆ FVC girls, ◇ FEV_1girls

A comparison of mean FEV_1 and FVC between subjects in this study and Caucasian children is given in Table 2 and shown graphically in Figs. 4 and 5. Caucasian children have significantly larger lung volume results ($P<0.001$) than subjects in this study. Differences

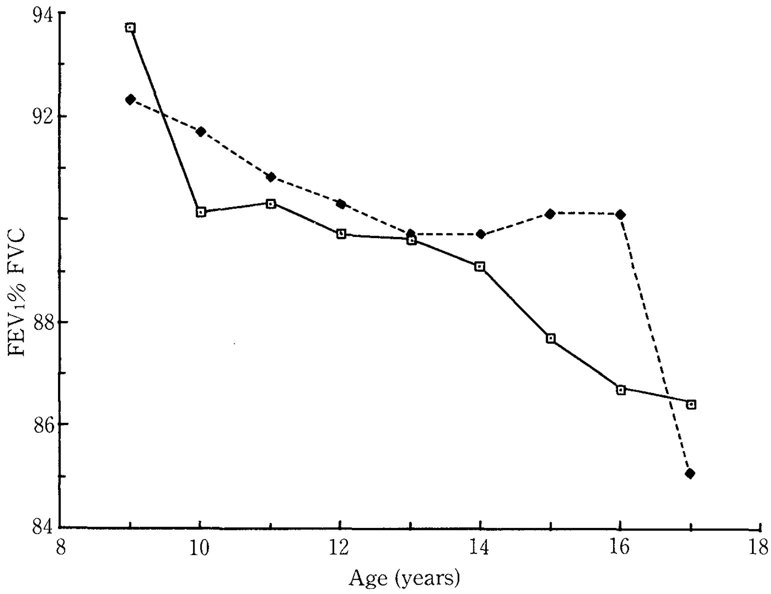

Fig. 2. Relationship of mean FEV1%FVC with age for Dar es Salaam school children.
◘ boys ◆ girls

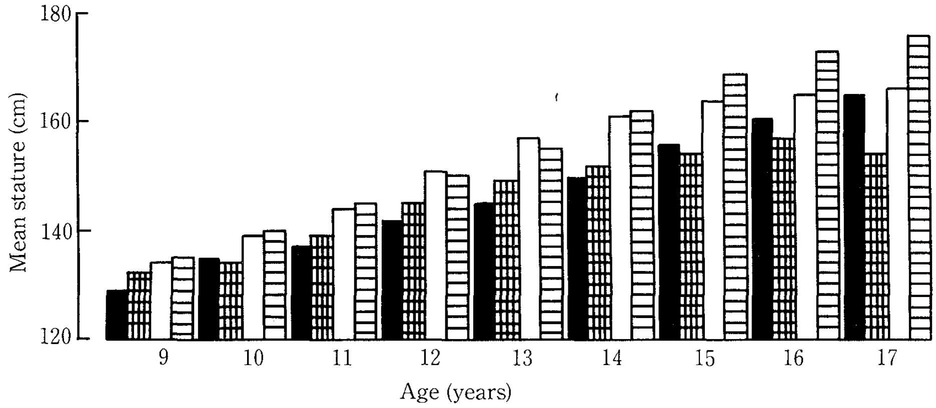

Fig. 3. Comparison of mean standing height at different ages between subjects in this study (TZ) and Caucasian subjects (C).
■ boys (TZ), ▦ girls (TZ), ⊟ boys (C), □ girls (C)

range between 11−27% and 13−30% in the boys, and between 11−20% and 12−22% in the girls for FEV_1 and FVC respectively. Equations for predicting FEV_1 and FVC are given in Table 3. In all parameters, the power of the standing height derived from ln lung volume on ln H was greater than 3.00. In Table 4 predicted FVC and FEV_1 derived from equations in this study and FVC and FEV_1 computed when mean standing heights of subjects in this study were incorporated in the equations of Hsu *et al.*, (1979) are presented. There is good agreement in the predicted lung volume results in boys and girls.

Table 2. Mean FVC and FEV_1 (ml) for subjects in this study (Tanz) and mean values for Caucasian school children (Cauc)

		FVC (ml)			FEV_1 (ml)		
Sex	Age	Tanz	Cauc	%differ	Tanz	Cauc	%differ
Boys	9	1464	1699	16	1327	1522	15
	10	1706	1923	13	1527	1704	11
	11	1800	2165	20	1604	1900	18
	12	2022	2429	20	1784	2111	18
	13	2194	2715	24	1923	2338	22
	14	2452	3153	28	2129	2682	26
	15	2742	3567	30	2359	3004	27
	16	3068	3940	28	2615	3290	26
Girls	9	1479	1523	3	1330	1372	3
	10	1538	1716	12	1384	1533	11
	11	1739	1924	11	1553	1706	9
	12	1987	2244	13	1759	1970	12
	13	2186	2546	17	1923	2218	15
	14	2331	2763	19	2043	2393	17
	15	2403	2933	22	2101	2531	21
	16	2572	2991	16	2239	2578	15

%differ represent percent differences in the lung volumes between the two groups

Discussion

Different ways of approach to analysis and presentation of pulmonary function data have been described (Kamel *et al.*, 1965; Cole, 1975). In this study a power function was used to relate lung function indices with standing height, and linear regression analyses were performed without making corrections for errors in the measurements of standing height so that the estimated power of the power function would be small. We observed large slopes (power of the power function) for FEV_1 and FVC in boys and girls in this study supporting earlier observations that lung volume relates best to the cube of standing height (Cole, 1975; Schrader *et al.*, 1984).

Significant differences in pulmonary functions between sexes have been demonstrated (Guerini *et al.*, 1970; Cogswell *et al.*, 1975) while others have not (Weng & Levison, 1969; Michaelson et al., 1978). Boys and girls were analyzed separately in this study. We observed that for the same standing height within the range of 130 — 155 cm, girls have about 9.5% smaller FEV_1 and FVC than boys; thus stressing that boys and girls should always be analyzed separately. In the boys, annual increment in the standing height and lung function indices is highest between 13 — 15 years while in girls it is between 11 — 14 years. These observations agree with reports on Caucasians where similarly, girls have accelerated growth in stature and lung volume two years earlier than boys (Schrader *et al.*, 1984; De Groodt, 1986).

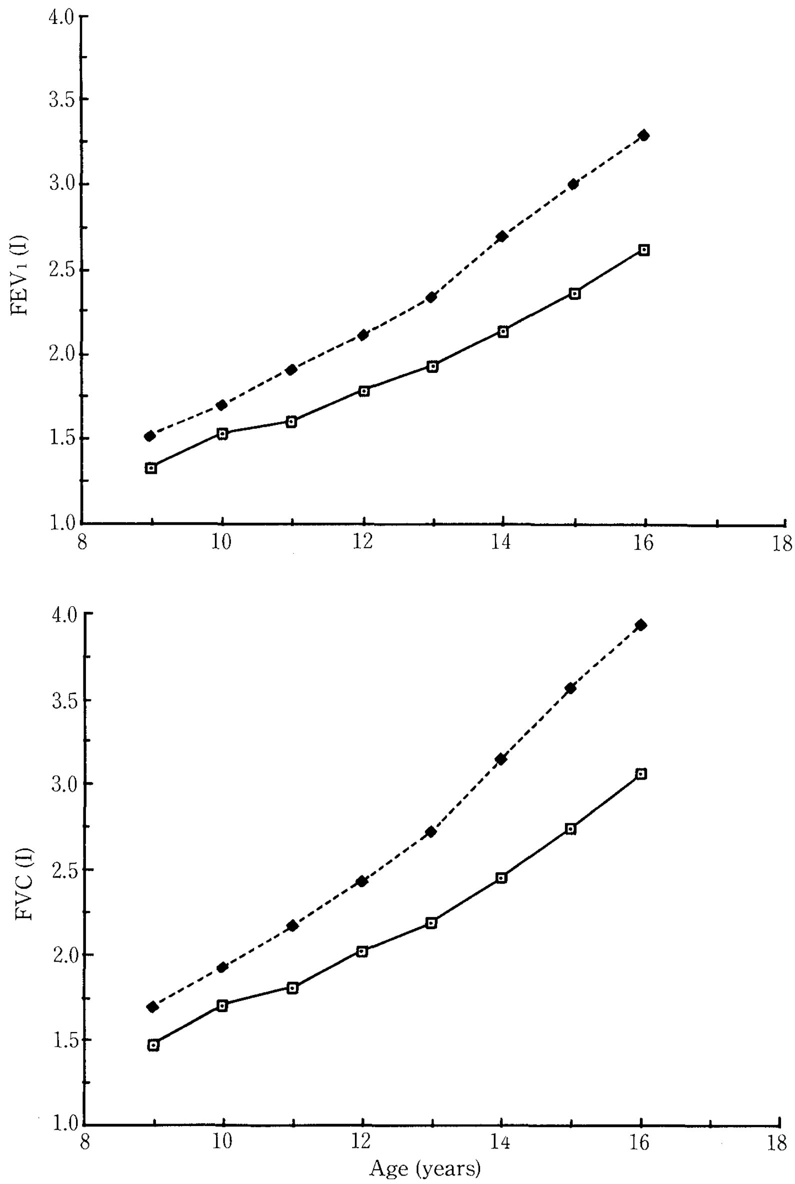

Fig. 4. Comparison of predicted FEV_1 and FVC values (l) of boys in this study (TZ) and values in Caucasian boys (C) at different ages when mean standing height of Caucasian boys was used in equations constructed in this study.

◘ boys (TZ) ◆ boys (C)

Comparison of FEV_1 and FVC in this study with data on Caucasians (Schrader *et al.*, 1984) shows that subjects in this study have smaller FEV_1 and FVC than Caucasians of comparable ages. Similarly, for the same standing height, FEV_1 and FVC results of subjects in this study are smaller than those found in their white counterparts. The differences agree with earlier reports (Chehreh *et al.*, 1973; Binder *et al.*, 1976; Schoenberg *et al.*, 1978; Hsu *et al.*, 1979), stressing that extrapolation of Caucasian sets of "normal" values to other populations is misleading and hence the need for each population to compile reference values applicable to their populations.

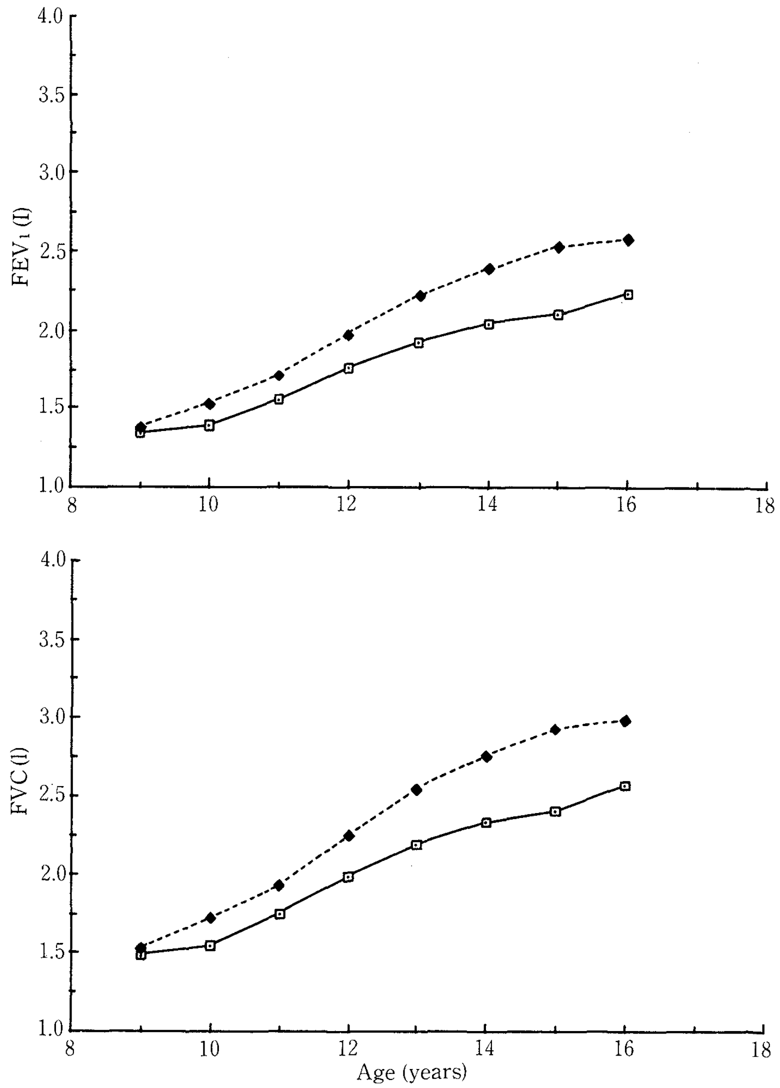

Fig. 5. Comparison of predicted FEV_1 and FVC values (l) of girls in this study (TZ) and values in Caucasian girls (C) at different ages when mean standing height of Caucasian girls was used in equations constructed in this study.

□ girls (TZ) ◆ girls (C)

Table 3. Prediction equations for FVC and FEV_1 (ml) for school boys and girls in Dar es Salaam, and prediction equations for FVC and FEV_1 in children of African origin (Hsu *et al.*, 1979) showing closeness of the power of standing height (H)

Author	Index	Sex	N	Regression equation	RSD	r
This study	FVC	M	726	$102\times10^{-6}\times H^{3.39}$	0.150	0.88
		F	687	$193\times10^{-6}\times H^{3.24}$	0.167	0.79
	FEV_1	M	726	$361\times10^{-6}\times H^{3.11}$	0.144	0.88
		F	687	$488\times10^{-6}\times H^{3.03}$	0.168	0.76
Hsu *et al.*						
(1979)	FVC	M	216	$1070\times10^{-6}\times H^{2.93}$		0.90
		F	311	$834\times10^{-6}\times H^{2.98}$		0.89
	FEV_1	M	216	$1030\times10^{-6}\times H^{2.92}$		0.89
		F	311	$1140\times10^{-6}\times H^{2.89}$		0.88

Table 4. Computed FVC and FEV_1 (ml) using prediction equations in this study as compared to computed FVC and FEV_1 when mean standing height of subjects in this study was incorporated in the equations of Hsu *et al.*, (1979)

Author	Index	Sex	Age in years 9	11	13	15
This study	FVC	M	1463	1801	2194	2742
		F	1479	1739	2186	2402
	FEV_1	M	1326	1604	1923	2359
		F	1335	1553	1923	2100
Hsu *et al.* (1979)	FVC	M	1641	1963	2329	2824
		F	1771	2055	2535	2765
	FEV_1	M	1505	1799	2133	2584
		F	1559	1801	2208	2402

FEV_1 and FVC increases with age in both boys and girls, however, the ratio of FEV_1 to FVC declines gradually suggesting that during adolescence FVC outgrows FEV_1 in these subjects. FEV_1%FVC values reported in this study are somewhat larger than those reported in Caucasians (Schrader *et al.*, 1984; De Groodt, 1986) despite subjects in this study having smaller lung volumes. It has been suggested that people of African trait have large lung elastic recoil than Caucasians (Binder *et al.*, 1976) which gives them a smaller FVC and large FEV_1%FVC. Lung elastic recoil was not measured in this study thus its contribution to the differences in the lung volumes between the two races could not be made. Studies of pulmonary function tests and elastic recoil to include large populations of rural children would unquestionably be helpful in a more clear assessment of Tanzanian values.

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タンザニアにおける小児の努力性肺活量と1秒量

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要　旨: 8歳から18歳までの健康な児童1,413人について，肺機能，特に努力肺活量（FVC），1秒量（FEV_1），1秒率（FEV_1%FVC）についてのデータを得た．被検者はすべて非喫煙者で，心血管系の症状や既往歴はない．この研究の被検者は，西洋の小児に比べ有意に身長が低く（$P<0.05$），同年齢・同身長ではFVC，FEV_1が有意に小さかった（$P<0.001$）．肺気量は，立位身長のべき乗の関数で近似される（$Y=aH^b$）．両対数グラフで導かれるFVCと身長のべき数は男子3.39，女子3.24であり，FEV_1と身長のべき数は男子3.11，女子3.03であった．この予測式より得られるFEV_1とFVCは，カリブの黒人小児に対しての同様な数学的モデルに基づく予測式により計算されるFEV_1とFVCとよく一致した．

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