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VENTILATORY CAPACITY INDICES IN MALAWIAN CHILDREN
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ABSTRACT

Objective: **To compare ventilatory capacity indices in healthy Malawian school children with those of other ethnic Africans and Caucasians.**
Design: **Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR), FEV_1 expressed as a percentage of FVC (FEV%), weight and height.**
Setting: **Two primary schools in urban Blantyre, Malawi.**
Subjects: **Five hundred and fourteen apparently healthy school children (230 boys and 284 girls) aged six to 17 years.**
Results: **Ventilatory capacity indices (FEV_1, FVC and PEFR) strongly and significantly correlated to body size and age of children of both sexes. The mean value of FEV % was 88.3% and it did not change significantly with increasing body size and age of children. The mean values of FEV_1 and FVC were 9.8 % and 10.8% higher in boys than in girls, respectively. The 1.4 % gender difference in PEFR values was statistically non-significant. For FEV_1 and FVC values, the average differences between Malawian and European children were between 20.5% and 23% while for PEFR the ethnic difference was about 12%. The Malawian children have similar ventilatory capacity indices to those of Nigerian, Jamaican and Tanzanian children.**
Conclusion: **Prediction equations calculated in this study should be used for interpretation of ventilatory capacity indices in Malawian children instead of reference values for Caucasians or ethnic scaling factors. Computation of regional reference values for ventilatory capacity indices shall be continued. It shall embrace additional factors contributing to variance in respiratory functions such as customary physical activity, local environmental conditions, altitude of residence, nutritional status and smoking.**

INTRODUCTION

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR) and FEV_1 expressed as a percentage of FVC (FEV%) are commonly used in physiology, clinical sciences, community and occupational medicine for assessment of ventilatory capacity in children and adults in variety of circumstances. In children these indices are also used for assessment of general growth and development as they increase in proportion with changes in anthropometric variables(1,2). Ventilatory capacity parameters can be measured during single expiration but they characterise the functional state of the whole respiratory system including thoracic cage, respiratory muscles, lungs and control mechanisms of ventilation. FEV_1 and FVC are very reproducible and depend on the lung size. FEV% and PEFR are nearly independent from lung size and reflect mainly the calibre of large airways. PEFR is expiratory effort dependent.

Due to considerable ethnic variations in ventilatory capacity, appropriate local norms should be used for interpretation. Reference values for western populations are widely available(1-5) but they are likely to mislead in interpretation of ventilatory capacity in ethnic Africans. Only a few studies of respiratory parameters of African children have been reported(6-8). In the situation of absence of local norms, some authors(2,9) recommended to apply conversion factors for adjusting western reference values to persons of other ethnic groups. Such approach might also be misleading as it does not take into consideration environmental and ethnic diversity of the continent as well as differences in growth pattern between western and African children. In the present study we examined ventilatory capacity indices of healthy Malawian children and compare them with western norms and limited data for ethnic African children.

MATERIALS AND METHODS

The subjects were 514 primary school children (230 boys and 284 girls) who were attending two state schools in urban Blantyre, the largest city in Malawi. The city lies at about 1000 metres above sea level. All measurements were done between 9 a.m. and 12 noon at schools with ambient temperature of about 22°C. Approval from health and educational authorities was obtained. One class in each grade was selected randomly. Subjects were recruited on the basis of informed consent. All subjects were non-smokers and had neither symptoms nor history of cardiopulmonary diseases or signs of chest deformity.

Height and weight of children were measured using a beam balance and a stadiometer and the standard technique described elsewhere (10). Beam balance was calibrated regularly using a set of weights. The children were weighted in light clothes and without shoes. Height was recorded to the nearest millimetre and weight to the nearest 0.1 kilogram. Age was accurately registered for all children and reported to the nearest whole year.

The expiratory parameters measured were forced expiratory volume in one second (FEV_1), forced vital capacity (FVC) and peak expiratory flow rate (PEFR). FEV_1 was also expressed as the percentage of FVC (FEV%). The measurements were taken using Spirocheck apparatus (P.K. Morgan Ltd., England) in the standing position. A nose clip was used for the measurements. The subjects were instructed to make a maximal inspiratory effort, to place the mouthpiece in the mouth and to blow out with a maximal expiratory effort. Adequate demonstrations were also made on the apparatus and the subjects were actively encouraged during the measurement to blow out maximally. Three technically satisfied measurements were taken and the maximal values were registered. They were corrected to body temperature and an aqueous vapour pressure at 37°C. At least 30 seconds were allowed between each blow. The calibration of the apparatus was performed regularly with a precision syringe.

Epi Info and Microsoft Excel computer software were used for statistical analysis of the results. Data are presented as means and standard deviations of means. Two-tailed P test was used to compare mean values. A P value of less than 5% was taken as indicating statistical significance. Linear regression was used to assess trend.

RESULTS

Tables 1-4 show the mean values and SD of the ventilatory capacity indices tabulated according to age and standing height of Malawian boys and girls. There was strong and significant correlation between expiratory indices (FEV_1, FVC and PEFR) and body size and age of children of both sexes (Table 5). The highest values of correlation coefficient were between the standing height and ventilatory capacity indices. The mean values of FEV% for boys and girls were 88.0±9.6% and 88.4±10.5% respectively and they did not change significantly with increasing body size and age of children. The mean values of FEV_1 and FVC were 9.8 % and 10.8% higher in boys than in girls (p=0.011 and p=0.004 respectively). The 1.4% gender difference in PEFR values was statistically non-significant.

Table 1

Anthropometric and ventilatory capacity parameters (mean ± SD) in Malawian boys by age at last birthday

Age (yrs)	No.	Height (cm)	Weight (kg)	FEV_1 (litres)	FVC (litres)	PEFR (litres/min)	FEV%
6	12	108.6±2.8	18.7±2.6	0.91±0.20	1.04±0.23	143.4±30.7	87.4±0.7
7	22	115.2±1.8	20.4±1.4	1.03±0.21	1.20±0.25	164.8±33.1	87.1±7.2
8	20	120.5±1.8	22.5±1.5	1.17±0.24	1.33±0.21	193.6±33.1	87.8±12.9
9	16	126.1±0.9	25.0±1.9	1.25±0.25	1.48±0.30	226.6±39.4	86.0±9.8
10	14	129.7±1.7	26.7±2.3	1.42±0.28	1.59±0.35	242.9±48.9	90.3±8.2
11	13	134.4±1.9	28.8±3.6	1.50±0.38	1.87±0.41	256.6±44.1	82.7±13.1
12	18	138.8±1.4	30.6±3.2	1.63±0.31	1.79±0.35	287.5±45.9	91.0±5.3
13	30	145.7±2.3	35.6±3.8	1.96±0.35	2.27±0.37	308.8±61.6	87.3±12.1
14	28	152.7±1.5	41.4±4.7	2.20±0.31	2.56±0.41	370.6±62.9	86.6±7.6
15	21	159.0±1.8	47.3±6.4	2.53±0.41	2.81±0.47	378.7±58.3	90.4±5.1
16	20	163.9±1.6	53.4±5.3	2.55±0.31	2.88±0.38	420.1±50.9	89.1±5.7
17	13	172.1±4.9	56.9±6.1	2.92±0 44	3.28±0.53	432.6±40.4	89.0±4.4

Table 2

Anthropometric and ventilatory capacity parameters (mean ± SD) in Malawian girls by age at last birthday

Age (yrs)	No.	Height (cm)	Weight (kg)	FEV_1 (litres)	FVC (litres)	PEFR (litres/min)	FEV%
6	13	110 0±1 2	18.4±1.3	0.83±0.30	1.00±0.36	116.8±39.0	84.3±11.3
7	28	115.0±2.1	19.4±1.5	0.95±0.30	1.11±0.38	178.1±45.4	86.8±9.7
8	16	119.7±4.1	21.3±1.3	1.09±0.34	1.26±0.35	183.8±48.7	86.8±9.0
9	27	123.6±2.0	24.0±3.8	1.16±0.28	1.40±0.38	224.3±71.6	84.1±9.8
10	16	128.9±8.9	27.7±2.2	1.28±0.24	1.43±0.25	221.1±62.1	90.0±4.4
11	29	134.9±2.1	28.9±2.4	1.39±0.27	1.58±0.26	250.2±54.9	89.2±1.4
12	29	142.3±2.4	36.5±6.7	1.65±0.33	1.85±0.38	312.1±75.2	89.6±9.8
13	25	148.0±1.5	43.7±6.4	1.87±0.40	2.13±0.41	327.5±79.1	88.6±2.2
14	29	151.7±8.9	44.8±4.2	2.06±0.43	2.23±0.42	365.8±89.3	91.8±4.2
15	32	155.0±1.4	51.2±5.0	2.15±0.36	2.38±0.46	386.5±81.1	91.4±7.8
16	24	159.0±7.8	53.7±10.1	2.24±0.45	2.64±0.55	373.9±90.5	86.7±8.7
17	16	164.4±3.8	54.1±6.2	2.55±0.35	2.90±0.36	418.6±46.5	88.0±5.6

Table 3

Weight and ventilatory capacity indices (mean ± SD) in Malawian boys aged six to seventeen years by standing height.

Height (cm)	No	Weight (kg)	FEV1		FVC		PEFR		FEV%
			litres	%#	litres	%#	litres	%#	
105.0-109.9	10	18.7±2.7	0.81±0.23	79.5	1.04±0.26	74.1	145.0±42.5	90.6	87.5±7.4
110-104.9	11	19.1±0.8	1.06±0.13	88.0	1.21±0.22	80.8	155.9±36.1	86.6	88.3±9.6
115-119.9	21	21.4±1.5	1.09±0.27	78.0	1.26±0.32	73.9	178.0±40.0	34.7	86.9±5.1
120-124.9	15	23.0±1.6	1.19±0.25	77.0	1.37±0.21	74.0	203.7±44.5	88.6	87.2±13.2
125-129.9	21	23.3±1.5	1.31±0.26	76.8	1.53±0.37	74.5	233.5±51.1	88.1	869±9.5
130.0-134.9	14	28.7±3.2	1.47±0.37	77.6	1.67±0.37	74.3	248.9±53.2	88.9	89.5±9.6
135.0-139.9	17	29.2±3.3	1.60±0.33	84.5	1.83±0.38	81.5	269.5±60.8	96.2	88.4±9.6
140.0-144.9	19	32.8±3.1	1.71±0.41	81.2	1.96±0.41	78.2	283.6±58.6	90.0	88.6±12.4
145.0-149.9	16	37.6±2.9	2.03±0.27	81.3	2.43±0.30	83.8	335.1±64.7	90.6	84.2±9.5
150.0-154.9	25	40.2±4.2	2.18±0.31	78.4	2.48±0.42	77.6	357.8±63.9	90.6	88.7±8.8
155.0-159.9	16	45.8±3.1	2.42±0.33	80.8	2.71±0.37	77.7	383.8±56.4	91.4	89.7±9.5
160.0-164.9	24	51.1±7.4	2.54±0.37	77.1	2.86±0.41	76.3	404.3±42.1	90.9	89.2±4.0
165.0-169.9	13	53.3±3.5	2.70±0.36	76.1	3.05±0 42	76.3	412.6±48.2	87.8	88.7±5.2
170+	8	60.8±5.7	3.04±0.42	77.9	3.44±0.43	76.4	443.7±42.1	88.7	88.5±5.1

Represents values relative to corresponding norms for European children (2)

Table 4

Weight and ventilatory capacity indices (mean ± SD) in Malawian girls aged six to seventeen years by standing height

Height (cm)	No	Weight (kg)	FEV1		FVC		PEFR		FEV%
			litres	%#	litres	%#	litres	%#	
105-109.9	6	18.7±1.8	0.80±0.26	79.7	0.91±0.36	72.4	143.6±28.6	89.7	89.8±5.3
110-114.9	24	18.5±1.8	0.91±0.28	88.4	1.09±0.38	80.8	154.8±56.8	86.0	85.7±9.9
115-119.9	17	20.2±1.2	1.00±0.36	79.7	1.18±0.37	75.9	171.2±48.3	81.5	84.1±9.2
120-124.9	24	22.4±1.9	1.11±0.29	79.0	1.30±0.35	78.9	202.7±68.4	87.9	86.0±9.3
125-129.9	27	26.6±4.9	1.24±0.29	80.1	1.40±0.33	75.8	229.3±58.4	86.6	88.7±5.6
130-134.9	16	28.2±3.0	1.34±0.24	76.6	1.56±0.23	77.9	249.1±59.3	89.0	86.4±11.1
135-139-9	20	30.5±2.2	1.49±0.27	78.3	1.65±0.26	73.2	273.7±63.2	86.9	91.0±11.5
140-144.9	14	35.9±6.8	1.66±0.47	77.2	1.84±0.42	74.9	282.7±84.2	83.1	89.9±9.6
145-149.9	43	43.4±6.6	1.83±0.35	76.2	2.09±0.46	80.4	338.1±68.6	91.3	88.9±11.2
150-154.9	40	46.4±5.9	2.08±0.44	79.8	2.28±0.42	7.86	361.5±72.9	91.5	90.8±11.0
155-159.9	30	52.4±5.2	2.13±0.42	76.2	2.45±0.50	77.9	384.0±82.5	91.4	88.6±9.5
160-164.9	15	52.9±5.2	2.44±0.42	73.7	2.76±0.48	81.2	402.7±53.1	90.5	78.7±12.6
165-169.9	8	57.4±4.6	2.70±0.21	81.7	3.00±0.22	83.3	423.5±30.3	90.1	89.9±2.3

Represents values relative to corresponding norms for European children (2)

Table 5

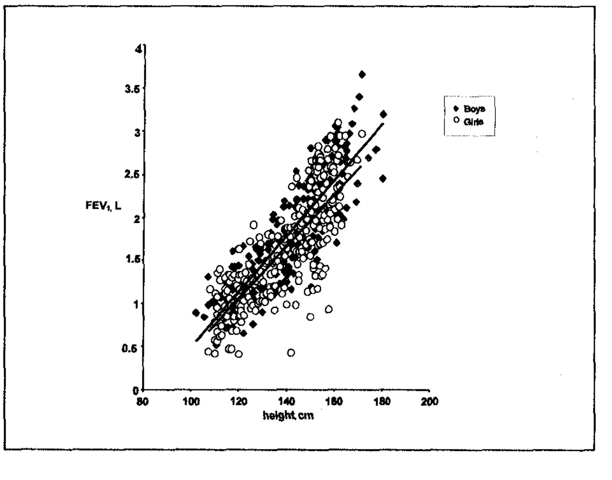
Correlation coefficients between ventilatory capacity indices and body size measurements in Malawian children.

Criterion	Gender	Age (years)	Height (cm)	Weight (kg)
FEV1 (litres)	Boys	0.79*	0.87*	0.84*
	Girls	0.76*	0.80*	0.76*
FVC (litres)	Boys	0.79*	0.85*	0.84*
	Girls	0.75*	0.78*	0.75*
PEFR (litres/min)	Boys	0.76*	0.84*	0.80*
	Girls	0.64*	0.68*	0.62*
FEV %	Boys	0.01	0.06	0.03
	Girls	0.11	0.14**	0.10

* Indicates significant correlation coefficient at P<0.001
** Indicates significant correlation coefficient at P<0.05

Figure 1

Scattergram showing the relationship between FEV_1 and stature in Malawian children



Data adjusted for standing height (Tables 3 and 4) were also expressed as percentage of corresponding norms for European children(2). The European children had systematically higher values than Malawian children. For FEV_1, FVC and in both sexes, Malawian values averaged 77% to 79% relative to norms for Caucasians and remained virtually unchanged with increasing body size. Relative values of PEFR were 89.8% and 88.5% in boys and girls respectively and also did not depend on body size.

For all indices of ventilatory capacity the relationship to anthropometric parameters and age was linear. This is demonstrated in Figure 1 for FEV_1 and standing height of children as an example. Therefore logarithmic transformation of data was not made and linear regression was used to describe the trend in changes of ventilatory capacity indices with increasing body size and age of children. The following equation best describe the data:

For boys: $FEV_1 = 0.033\ H - 2.828$

$FVC = 0.036\ H - 3.012$

$PEFR = 4.922H - 397.8$

For girls: $FEV_1 = 0.030\ H - 2.542$

$FVC = 0.033\ H - 2.751$

$PEFR = 5.189\ H - 432.5$

Using these prediction equations the ventilatory capacity indices were 99.6% to 101.0% predictable in children of both sexes.

DISCUSSION

The present data relate to a relatively small sample of healthy Malawian school children from urban Blantyre. However, the schools selected for this survey are typical for urban and semi-urban areas in the country and the findings seem to be representative of that population of children.

The pattern of growth of ventilatory capacity in Malawian children was similar to that reported in other studies(6-9,12-14). It resembled the pattern of physical growth. Like in other studies(1,2,6-8), the relationship between lung function and body size was best expressed in terms of height in Malawian children. The onset of adolescence did not considerably influence the relationship between the indices of maximal ventilatory capacity and anthropometric variables. This is also in agreement with published data(2). After allowing for standing height, the lung volume dependent parameters (FEV_1 and FVC) in boys were generally higher than in girls while indices representing airway calibre (FEV% and PEFR) were almost equal in both sexes.

FEV_1 and FVC values of Malawian children were on average 20.5% to 23% smaller than European reference values(2) and the difference persisted after standardising for stature. Therefore the ethnic difference in lung volume dependent ventilatory capacity parameters was higher than the 13% scaling factor(9) for adjusting European norms to ethnic Africans. Introduction of the scaling factor was based on the 13% ethnic differences in body shape, particularly the size of thoracic cage, between Caucasians and ethnic Africans(2,9,15) with Caucasians having larger lung volume than Africans. Our data indicate that neither European norms for FEV_1 and FVC nor the scaling factors could be used for interpretation of lung volume dependent indices in Malawian children. Prediction equations calculated in this study should be used instead. We can also speculate that factors other than lung size might affect volume dependent respiratory parameters. For example, it has been demonstrated(16) that inadequate nutrition has a profound quantitative and qualitative affects on lung growth and development and ventilatory capacity correlates significantly with nutritional indexes. The nutritional status of children was not assessed in this study. However published data(15,17) indicate the high level of mulnutrition in Malawi and this may contribute to low values of FEV_1 and FVC in Malawian children.

The values of FEV% of Malawian and European children were similar and those for PEFR were lower but the ethnic difference was lesser than that for FVC and FEV_1 These facts confirm the suggestion that indices representing airway calibre are relatively independent of ethnicity(2).

FVC and FEV_1 of Malawian children were five to seven per cent lower than in Sudanese and Libyan children and they were similar to those of Nigerian, Tanzanian, and Jamaican children(6-8,12,14). This indicates that in the absence of local norms, reference values for other ethnic African populations are a better choice than European norms.

In conclusion, prediction equations calculated in this study should be used instead of reference values for Caucasians or ethnic scaling factors for interpretation of ventilatory capacity indices in Malawian children. Computation of regional reference values for ventilatory capacity indices shall be continued. It shall embrace additional factors contributing to variance in respiratory functions such as customary physical activity, local environmental conditions, altitude of residence, nutritional status and smoking.

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REFERENCES

1. Cotes, J.E., Dabbs, J.M., Hall, A.M., Heywood, C. and Laurence, K.M. Sitting height, fat-free mass and body fat as reference variables for lung function in healthy British children: comparison with stature. *Ann. Hum. Biol.* 1979; **6**:307-314.
2. Cotes, J.E. Lung Function: Assessment and Application in Medicine, 5th ed. Oxford: Blackwell Scientific Publication, 1992.

3. Dickman, M.L., Schmidt, C.D. and Gardner, R.M. Spirometric standards for normal children and adolescents. *Amer. Rev. Resp.* Dis. 1971; **104**:680-687.
4. Van Pelt, W., Quanjer, Ph.H., Borsboom, G., Paoletti, P., Di Pede, F, Viegi, G *et al.* Comparability of reference populations from Holland and Italy. *Eur. Resp. J.* 1990; **3**:158.
5. Wille, S. and Svenson, K. Peak flow in children aged 4-16 years. Normal values for vitalograph peak flow monitor, Wright and mini-Wright peak flow meters. *Acta Paediat. Scand.* 1989; **78**:544-584.
6. Mabrouk, A.A.M. and Ibrahim, S.A. Normal values for lung function tests in Sudanese children. *East Afr. Med. J.* 1995; **72**:258-262.
7. Oduwole, O., Aderele, W. I. and Tweedle, M.C.K. Ventilatory capacity in Nigerian school children. *Ann. trop. Paediat.* 1983; **3**:103-109.
8. Mashalla, Y.J., Masesa, P.C. and Veeneklaas, R.J. Prediction of normal forced vital capacity and forced expiratory volume in one second in Tanzanian children. *Sangyo Ila Daigaku Dasshi.* 1990; **12**:389-398.
9. Rossiter, C.E. and Weill, H. Ethnic difference in lung function; evidence for proportional differences. *Int. J. Epidem.* 1974; **3**:55-61.
10. Gibson, R.S. Principles of Nutritional Assessment. NY: Oxford University Press. 1990.
11. Patrick, J.M. and Patel, A. Ethnic differences in the growth of lung function in children: a cross-sectional study in inner-city Nottingham. *Ann. Hum. Biol.* 1986; **4**:307-315.
12. Mukhtar, M.S., Rao, G.M., Morghom, L.O. and Patrick, J.M. Spirometric standards of Libyan boys and girls. *Respiration,* 1989; **56** 227-234.
13. Anderson, H.R., Anderson, J.A. and Cotes, J.E. Lung function values in healthy children and adults from highland and coastal areas of Papua New Guinea. *Papua New Guinea Med.J.* 1974;**17**:165-167.
14. Miller, G.J., Sauders, M.J., Gilson, R.J.C. and Ashroft, M.T. Lung function in healthy boys and girls in Jamaica in relation to ethnic composition, test exercise performance and habitual physical activity. *Thorax..* 1977; **32**:486-496.
15. Patrick, J.M. Ventilatory capacity in tropical populations: constitutional and environmental influences. Variations in Working Capacity in Tropical Populations. Cambridge: Cambridge University Press, 31-48, 1986.
16. Ong, T.J., Mehta, A. Ogston, S., and Mukhopadhyay, S. Prediction of lung function in the inadequately nourished. *Arch. Dis. Child.* 1998; **79**:18-21.
17. Pelletier, S.I., Low, J.W. and Msukwa, L. A. H. Malawi maternal and child nutrition study: study design and anthropometric characteristics of children and adults. *Amer. J. Hum. Biol.* 1991; **3**:347-364.
18. Quinn, V.J., Chiligo-Mpoma, M.O., Simler, K. and Milner, J. The growth of Malawian pre-school children from different socioeconomic groups. *Eur. J. Clin. Nutr.* 1995; **49**:66-72.