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Normative values and anthropometric determinants of lung function indices in rural Nigerian children: A pilot survey

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Abstract *Introduction:* Respiratory diseases represent some of the most common causes of hospital visits in childhood. Most of our decision making rely on clinical assessment without the benefit of objective measures of pulmonary function. The ability to measure pulmonary function provides a tool that can confirm clinical diagnosis, monitor response to therapy and follow progression of disease. Correct interpretation of pulmonary function test requires an appreciation of normal values.

Patients and methods: Lung function test was performed on rural children in Akwa Ibom State, Nigeria, to determine normal values among healthy children. One hundred and fifty two children aged 6-16 years old comprising 89 males and 63 females were included in this study. Anthropometric measurements including height, weight, sitting height, chest circumference and body surface area were obtained. The Peak Expiratory Flow (PEF), forced vital capacity (FVC) and Forced Expiratory Volume in one second (FEV_1) were measured using the *spirolab III* electronic spirometer manufactured by Medical International Research (MIR) Italy. It was a descriptive cross sectional study.

Results: One hundred and fifty-five children; 89 (58.6%) males and 63 (41.4%) females were studied. The mean age (±SD) of the males was 10.5$\pm$2.95 years while that of the females was 10.7 $\pm$ 3.19 years. The mean PEFR, FVC and FEV_I were 3.95±1.55 litres per second (l/s) 1.58±0.58 litres (l) and 1.57±0.56l in the males while for the females 3.73±1.03l/s, 1.45±0.43l and 1.41±0.41l respectively. The FVC and FEV1 of the males were significantly higher than that of the females (p=0.03 respectively). Height was the significant predictor of PEFR (p=0.04), while the height and sitting height were the important predictors of log FVC and FEV_1 for the males respectively (p= 0.007 and 0.02; 0.004 and 0.027). For the female subjects, age was a significant predictor of log PEFR and Log FVC (p=0.047 and 0.003), while Age and Sitting height were the significant predictors of log FEV_1 (p=0.02 and 0.03 respectively).

Conclusion: The study has observed higher lung function indices in the males than in female children. In addition to age and height, sitting height has been observed as an important predictor of the lung function indices of the children studied. This study should be seen as a pilot study and will require data from a large population to establish normal values for our population.

Key words: Lung function, rural, children, anthropometric determinants

Introduction

Pulmonary function tests range from simple measurements of peak flow and pulse oximetry to complex evaluations of absolute lung volume and diffusing capacity[1]. Lung functions vary in healthy people and are greatly influenced by individual weight, height, age, sex, race, nutrition, body surface area and environmental factors. [2,3]. Objective measurements of pulmonary function can be useful in the diagnostic evaluation of children who have a cough, exercise limitation, or other symptoms and signs referable to the respiratory system.

Correct interpretation of lung function test requires an appreciation of normal values. Normal values for individuals of same age, gender, height and race are available from prediction formulae or reference tables for the Caucasian population.[4]

Reports on pulmonary function studies have been scanty in Nigeria and mostly involve the estimation of peak expiratory flow rate.[5-9] Lung function measurements made in Nigerian children are compared to Caucasian or African-American children since there are few records of spirometric studies to determine a range of normal values.[8,9] However, this is unsatisfactory as reports have shown children of African descent to have lower values than their Caucasian counterparts.[10-12]
This is an attempt therefore to establish a range of normal values and anthropometric determinants of some pulmonary function indices in healthy rural children from the southern rain forest region of Nigeria.

Subjects and methods

The subjects studied were normal healthy children with ages ranging from six to sixteen years living in Oyubia in Urue-Offong Oruko Local Government Area of Akwa Ibom State, Nigeria. The children were recruited from the only primary and secondary school in the community. This was a descriptive cross sectional study. Ethical clearance was obtained from the University of Uyo Teaching Hospital before embarking on the study. The community leaders were informed on the details of the study and written consent obtained Verbal consent was also obtained from parents and older children.
The following criteria were required for acceptance as normal subjects: (one) no history of cardiopulmonary disease. (two) The ability to cooperate adequately during the test, and (three) no physical evidence or history of disease which might affect pulmonary function. A respiratory questionnaire whose purpose was to identify any child with a history of or current respiratory illness was administered to the subjects. The socio-demographic data of the children, evidence of current acute respiratory tract infection (cough, phlegm, wheeze, chest tightness, nasal discharge, nasal congestion and fever), or past history of chronic pulmonary diseases and other illnesses that may limit activity were assessed using the respiratory questionnaire. The parents' socioeconomic status was also assessed using the Olusanya *et al* classification.[13] A general physical examination and a thorough clinical examination of the cardiopulmonary system were performed. This helped exclude any significant cardiopulmonary disease that would affect lung function. The subjects' standing height, sitting height, chest circumference and body weight were measured as per standard protocol,[14] while the body surface area was calculated using the Dubois and Dubois formula.[15]

All the lung function tests were performed in standing position using the Medical International Research (MIR) Spirometry machine, Spirolab *III* model no: 980067; year of make: 2007, Italy. Each test was performed three times with an interval of at least 30 seconds between readings and the best of three readings was recorded. The pulmonary function indices recorded included PEF, FVC and FEV_1.[16]

Data was analysed using STATA 10 (STATA Corp, Texas, USA). The Student t-test was used in comparing the means of continuous variables that were normally distributed. The Spearman rho test was used to measure the correlation of two continuous variables. Multivariate linear regression was used to determine the independent predictor of changes in the lung function indices of the study population. The results were expressed as means and standard deviations (SD). Data were summarized into frequency tables and charts. The p-value<0.05 was taken as statistically significant.

Results

One hundred and fifty- two children were recruited for the study. Eighty -nine (58.6%) of the subjects were males and 63 (41.4%) were females giving a male: female ratio of 1.4:1. The mean age of the males was 10.5±2.95 years, while that of the females was 10.7±3.19 years.
Twelve (7.9%) of the subjects belonged to social class II, and 140 (92.1%) belonged to social class III.
Table 1 shows the summary of the means of the measured variables. There was no statistically significant difference in the age and anthropometric parameters of both genders. Height for age was within the 3rd-97th percentile for 91.4% while, weight for age was within the same percentile for 90.2% of the subjects, using the Centre for Disease Control (CDC) growth chart.
The female subjects were heavier than the male subjects at ages 11 (30.6±4.89kg vs 27.6±3.34kg); p=0.09 and 12 (36.5±9.06kg vs 28.5±5.38kg); p=0.04 and were taller at ages 12 (143.9±5.25cm vs 137.2±6.28cm); p=0.03, 13 (153.3cm vs 146.6±5.12cm); p=0.04 and 14 (160.5±7.26cm vs 148.3± 9.32cm); p=0.20.

Table 1: Summary of the means of measured variables

Variables	Male (mean ± SD)	Female (mean ± SD)	*p-value*
Age (years)	10.50 ± 2.95	10.70 ± 3.19	0.92
Weight (kg)	29.60 ± 12.00	31.60± 11.91	0.78
Height (cm)	135.50±15.53	137.80±14.32	0.86
Sitting height (cm)	64.60± 8.95	66.30 ± 8.99	0.59
Chest circumference (cm)	80.80±6.24	66.50±10.16	0.51
Body surface area (m^2)	1.00± 0.26	1.10± 0.25	0.71
PEF (l/s)	3.95±1.55	3.67±1.03	0.23
FVC (l)	1.58±0.58	1.45±0.43	0.03**
FEV_1 (l)	1.57±0.56	1.41±0.41	0.03**

**Significant p-values

Table 2 shows the pulmonary function parameters of the subjects in relation to age and gender. The PEFR, FVC and FEV_1 of the males were significantly higher than that of the females at ages 15 and 16. p= 0.01 and 0.004, 0.04 and 0.001, 0.03 and 0.005 respectively. It was also shown that the PEFR, FVC and FEV_1 for ages 12 and 13 years were higher in the females but this did not achieve statistical significance.

Figure 1 and 2 shows the correlation of log PEFR, FVC and FEV_1 to sitting height in both the male and female subjects. The lung function indices all increased with increase in sitting height.

Table 2: Pulmonary function parameters of subjects in relation to age and gender

Age (yrs)	PEFR (L/S)			FEV_1 (L)			FVC (L)		
	M	F	*p*	M	F	*p*	M	F	*p*
6	2.36±0.61	2.26±0.55	0.73	0.96±0.12	0.89±0.19	0.42	0.98±0.15	0.90±0.19	0.36
7	2.71±0.60	2.65±0.60	0.80	1.14±0.24	0.99±0.01	0.21	1.17±0.25	1.01±0.12	0.20
8	3.10±0.62	2.91±0.66	0.61	1.23±0.15	1.11±0.17	0.19	1.26±0.27	1.12±0.16	0.17
9	3.60±0.39	3.51±0.43	0.71	1.19±0.11	1.15±0.08	0.46	1.23±0.11	1.18±0.08	0.43
10	3.48±0.55	3.63±0.77	0.62	1.36±0.20	1.23±0.13	0.15	1.40±0.06	1.28±0.11	0.18
11	3.75±0.72	3.76±0.96	0.98	1.47±0.18	1.38±0.24	0.28	1.56±0.20	1.42±0.23	0.12
12	3.34±0.81	4.31±1.04	0.06	1.56±0.34	1.64±0.23	0.61	1.64±0.37	1.67±0.25	0.84
13	3.89±0.71	4.36±0.11	0.35	1.78±0.12	1.83±0.15	0.54	1.82±0.14	1.85±0.14	0.60
14	5.26±1.28	4.81±0.19	0.66	1.84±0.21	1.93±0.37	0.72	1.88±0.20	1.94±0.35	0.77
15	6.58±1.03	4.96±0.58	0.01*	2.42±0.36	1.94±0.26	0.03*	2.46±0.39	2.00±0.05	0.04*
16	6.97±1.11	4.34±0.68	0.004*	2.96±0.48	1.92±0.24	0.005*	3.04±0.45	2.04±0.30	0.001*

*significant p-values
M=Male; F=Female; *p*=p-value

Fig 1 shows the relationship of log FVC, log PEFR and log FEV_1 to sitting height in the male subjects. The lung function indices all increased with increase in sitting height.

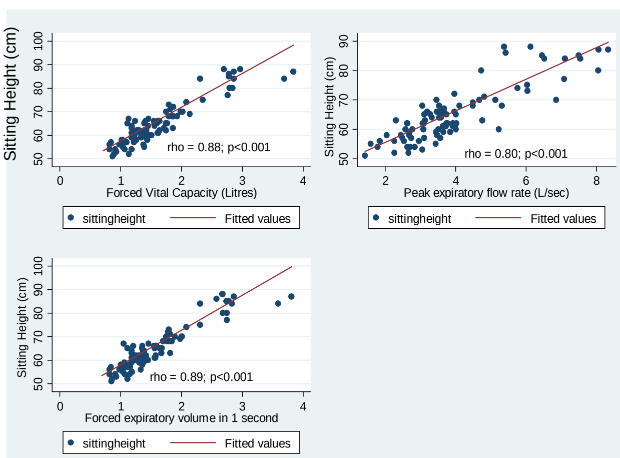

Fig 2 shows the relationship of log FVC, log PEFR and log FEV_1 to sitting height in the female subjects. The lung function indices all increased with increase in sitting height.

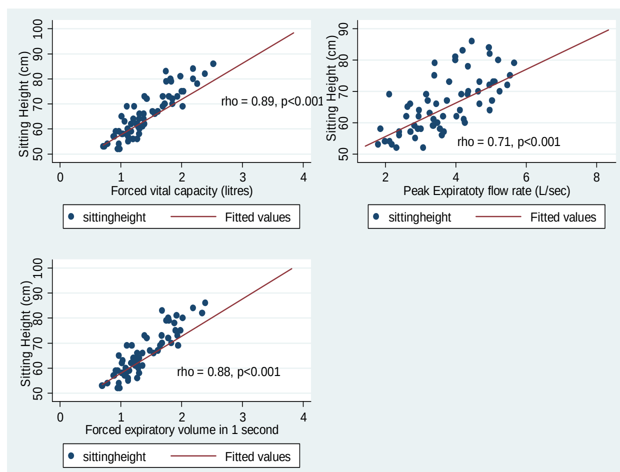

Table 3 shows the estimated normal ranges for the lung function indices measured in the subjects. These ranges were calculated using the mean ± 2SD values of the lung functions.

Table 3: Estimated normal ranges of pulmonary function indices by age and gender

Age (years)	PEFR (L/S)		FEV_1 (L)		FVC (L)	
	M	F	M	F	M	F
6	1.14-3.58	1.16-3.36	0.72-1.20	0.51-1.27	0.68-1.28	0.52-1.28
7	1.51-3.91	1.45-3.85	0.66-1.62	0.97-1.01	0.67-1.67	0.77-1.25
8	1.86-4.34	1.59-4.23	0.93-1.53	0.77-1.45	0.72-1.70	0.80-1.44
9	2.82-4.38	2.65-4.37	0.97-1.41	0.99-1.31	1.01-3.91	1.02-1.34
10	2.38-4.58	2.09-5.17	0.96-1.76	0.97-1.49	1.28-1.52	1.06-1.50
11	2.31-5.19	1.94-5.58	1.11-1.83	0.90-1.86	1.16-1.96	0.96-1.88
12	1.72-4.96	2.23-6.39	0.88-2.24	1.18-2.10	0.90-2.38	1.17-2.17
13	2.47-5.31	4.14-4.58	1.54-2.02	1.53-2.13	1.54-2.10	1.57-2.13
14	2.25-7.82	4.43-5.19	1.42-2.26	1.19-2.67	1.48-2.28	1.24-2.64
15	4.42-8.64	3.80-6.12	1.74-3.14	1.42-2.46	1.68-3.24	1.90-2.10
16	4.75-9.19	2.98-5.70	2.00-3.92	1.84-2.40	2.14-3.94	1.44-2.64

*the ranges were obtained using mean± 2SD

Tables 4 and 5, show the univariate and multivariate regression models showing the independent determinants of changes in the natural logarithms of PEFR, FVC and FEV_1 for both male and female subjects. For the male subjects: height (p=0.04) was the significant predictor of PEFR, while sitting height and height were independent predictors of changes in FVC and $FEV_{1.}$ (p=0.007 and 0.02; 0.004 and 0.027 respectively) For the female subjects, multivariate analysis showed age as the most significant predictor of log PEFR and Log FVC, (p=0.-47 and 0.03 respectively) while, age and sitting height were the most important predictors of log $FEV_{1.}$ (p=0.02 and 0.03 respectively)

Table 4: Univariate and Multivariate regression models showing the determinants of changes in log PEFR, log FVC and log FEV_1 for the male subjects

Parameter	Univariate analysis		Multivariate analysis	
	*β	p-value	*β	p-value
Log PEFR				
Age	0.09	<0.001**	0.014	0.44
Weight	0.02	<0.001**	0.018	0.35
Height	0.020	<0.001**	0.019	0.04**
Sitting height	0.034	<0.001**	0.012	0.09
BSA	1.013	<0.001**	-1.42	0.24
Chest circumference	0.034	<0.001**	0.004	0.59
#*Log PEFR = -1.51 + 0.019[height]*				
Log FVC				
Age	0.010	<0.001**	0.016	0.15
Weight	0.024	<0.001**	0.007	0.58
Height	0.020	<0.001**	0.016	0.007**
Sitting height	0.033	<0.001**	0.010	0.02**
BSA	1.138	<0.001**	-0.070	0.35
Chest circumference	0.034	<0.001**	0.004	0.34
#*Log FVC=-2.33=0.016(height* $_{cm}$*) + 0.010(sitting height)*				
Log FEV_1				
Age	0.010	<0.001**	0.010	0.260
Weight	0.024	<0.001**	0.007	0.540
Height	0.019	<0.001**	0.015	0.004**
Sitting height	0.033	<0.001**	0.009	0.027**
BSA	1. 150	<0.001**	-0.584	0.390
Chest circumference	0.035	<0.001**	0.005	0.280
#Log FEV1= -2.31+0.05(height)+0.009(sitting height)				

*beta the slope of the graph; **significant p values; #prediction equations

Table 5: Univariate and Multivariate regression models showing the determinants of changes in log PEFR, log FVC and log FEV_1 for the female subjects

Parameter	Univariate analysis		Multivariate analysis	
	*β	p-value	*β	p-value
Log PEFR				
Age	0.065	<0.001**	0.052	0.047**
Weight	0.014	<0.001**	-0.054	0.162
Height	0.014	<0.001**	-0.006	0.652
Sitting height	0.022	<0.001**	0.014	0.174
BSA	0.717	<0.001**	2.395	0.353
Chest circumference	0.018	<0.001**	0.002	0.839
#*Log PEFR= -0.41+0.052(age)*				
Log FVC				
Age	0.085	<0.001**	0.047	0.003**
Weight	0.021	<0.001**	-0.017	0.467
Height	0.019	<0.001**	0.003	0.719
Sitting height	0.030	<0.001**	0.011	0.076
BSA	1.029	<0.001**	1.010	0.516
Chest circumference	0.025	<0.001**	-0.008	0.164
#*Log FVC= -1.39+0.47(age)*				
Log FEV_1				
Age	0.082	<0.001**	0.037	0.020**
Weight	0.020	<0.001**	-0.008	0.740
Height	0.018	<0.001**	0.007	0.400
Sitting height	0.029	<0.001**	0.015	0.030**
BSA	0.991	<0.001**	0.217	0.892
Chest circumference	0.024	<0.001**	-0.004	0.458
#*Log* $FEV_{1=}$ *-1.74+0.037(age)+0.015(sitting height)*				

*beta the slope of the graph; **significant p values; #prediction equations

Discussion

In the present study, there was an increase of PEFR, FVC and FEV_1 with age; a feature that has been reported in earlier studies.[8,10,17] This is attributable to the fact that as a child grows the lung gets more elastic up to the age of 30-35 years.[18] With this increased elasticity there is an increase in lung volumes and capacities, but as a person gets older this natural elasticity of the lungs decreases, leading to reduced lung volumes and capacities.[18]

The PEFR, FVC, FEV_1 of the males in the present study, were higher than those of the females in the overall mean which is in keeping with the findings of Glew *et al*.[13] Neukrich *et al*[19] also observed higher FVC and FEV_1 in males than females in their series on Polynesian, European and Chinese teenagers. This is because of a gender dependent lung size difference, which is present even when males and females are matched for weight and height, the lung sizes of males are still greater than that of females, the reason for this is still unknown.[19]However, some studies have linked this observation to the higher values in the height and weight of the boys when compared to the girls at the different ages except during the adolescent growth spurt.[17,20]

The higher lung function indices observed in 12, 13 and 14 year old females than their male counterparts may be attributed to the higher values of the various anthropometric indices in the female subjects in this age range. The varying changes with different lung function indices at the age group mentioned may be attributed to the different peak growth velocities for different lung function indices as observed by Wang *et al*.[21] This increase in height and weight are attributed to the growth spurt in females which occurs earlier than that of males.[17,20] These observations are consistent with those made by Wang[18] and Rosenthal *et al*[22] who noted that during the female pubertal growth spurt all female spirometric values were higher than those of males. The finding in the current study is also consistent with that of Kivastik *et* *al*[23] who also noted that the growth spurt in sitting and standing height occurred between ages 11 and 13 years in girls, and 13 and 15 years in boys, with the growth spurts of their lung function parameters occurring during the same periods.

The significant predictors of PEFR, FVC and FEV_1 for the subjects in the current study were height and sitting height. This observation is similar to those of Aderele *et al*[7] and Olanrewaju[10] who reported pulmonary function values that correlated more with height than weight. This is probably because during childhood the lungs increase in proportion to the increase in height. The increase in height leads to increase in lung volumes and capacities.[24] Furthermore height can be accurately measured without the use of special equipment or technique; it is also less frequently abnormal than is weight, with chest disease.[13] Ip et al[25] also noted that the standing height and sitting height were equivalent predictors of lung volumes. The authors attributed this to the fact that sitting height or trunk length is the closest approximation of chest size of all the commonly used anthropometric parameter and recommended that in situations where standing height cannot be measured, sitting height is an adequate alternative.

It is worthy of note that for the male subjects height was the significant predictor of PEFR while, height and sitting height were significant predictors for the FVC and FEV_1. For the female subjects however, age was the independent predictor for PEFR and FVC while Age and sitting height were the predictors for FEV_1. These observations are similar to those of some south Indian children.[26]

With all these observations it could be possible that sitting height is not only a factor to be considered in differentiating between Caucasian and African lung function indices,[3] but should also be considered as a parameter in addition to standing height to be incorporated into prediction equations for calculating lung function in African children.

Conclusion

This study has attempted to provide a range of normative values for PEFR, FVC and FEV_1 for rural children in southern Nigeria. Sitting height has been observed to be an important predictor of lung function indices in these children. It is however imperative that a nationwide study be carried out to provide a pool for the establishment of normal spirometric values for Nigerian children.

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