Predicted Equations for Ventilatory Function Among Kuching (Sarawak, Malaysia) Population

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SUMMARY

Spirometry data of 869 individuals (males and females) between the ages of 10 to 60 years were analyzed. The analysis yielded the following conclusions:

1. **The pattern of Forced Vital Capacity (FVC) and Forced Expiratory Volume in One Second (FEV_1) for the selected subgroups seems to be gender dependant: in males, the highest values were seen in the Chinese, followed by the Malay, and then the Dayak; in females, the highest values were seen in the Chinese, followed by the Dayak, and then the Malay.**
2. **Smoking that did not produce respiratory symptom was not associated with a decline in lung function, in fact we noted higher values in smokers as compared to nonsmokers.**
3. **Prediction formulae (54 in total) are worked out for FVC & FEV_1 for the respective gender and each of the selected subgroups.**

KEY WORDS:
Spirometry Malays, Chinese, Dayaks, Predicted Equations

INTRODUCTION

Ethnic differences in pulmonary functions are recognized in adults and children[1,2] and information related to it and their predicted formulas are available for Asians,[2-12] Americans,[13] Europeans[14-16] and Africans[17,18]. However, there are no available prediction formulae values for lung functions of the various ethnic groups in Sarawak. Predicted values of pulmonary functions are based on many parameters, which include racial/ethnicity,[19-21] age, gender, body development,[22] and other physiological conditions. Despite these, many lung function laboratories fail to provide race specific reference values[23]. This is a cause for concern as the use of nonspecific prediction equations can lead to inaccurate interpretation of lung function[24,25].

Hence, the aim of this study is to determine the normal values of lung function i.e., Forced Vital Capacity (FVC) and Forced Expiratory Volume in One Second (FEV_1) of the population in Kuching (Sarawak, Malaysia). For that purpose, a cross-sectional epidemiological survey was done in the schools, university campus, police camp, offices, villages, mosque, and various workplaces.

MATERIALS AND METHODS

Subjects were recruited on a voluntary basis from individuals in Kuching (age ranging from 10 to 60 years). The study design was approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, Universiti Malaysia Sarawak.

After consents were obtained, recruited subjects were invited to fill in questionnaires, which included questions taken from ATS-DLD-78 questionnaire on respiratory symptoms[26]. Subjects' standing height was measured (without shoes on) and height recorded to the nearest centimeter with a stadiometer. Subjects' weight was taken (in light clothing and without shoes on) on a balance scale and weight was recorded to the nearest kg. Age was recorded to the nearest birthday in years.

Measurement of Lung Function

The spirometer used in this study is a Schiller Spirovit SP-1, a flow-detecting device (pneumotachograph) that fulfilled the standardization set by the American Thoracic Society[27]. The spirometer was calibrated in the morning before recording was made. After the nose-clip and mouthpiece was fitted, the subject/participant was urged to inhale deeply, and then to exhale through the mouthpiece as forcefully and completely, and as fast as possible. All the participants were guided through a minimum of three maneuvers of forced spirometry in standing position.

Analysis

Participants who had cough, phlegm, wheeze, and breathlessness and with value of FEV_1 less than 60% of FVC were excluded from analysis. In the younger age group, ventilatory function was observed to increase with increase in age. Expired airflow velocity increases steeply during growth, with peak reach between 20-25 years of age in male and 18-21 years of age in female. The peak value for FEV_1 is in the 20-23 years old, while the peak value for FVC is in the 25 years old. Thereafter, a steady decline in value was seen with increase in age,[28, 29]; for FEV_1, the annual loss is 28-30 mL/year[30].

As gender was among the reference variables and affected significantly the standard values, data analysis was done separately on the male and female. Also, as ventilatory function is affected by age, separate analysis was decided for each of the four age groups (divided by years of age): 10-19, 20-24, 25-44, and 45-60 for the male; 10-17, 18-22, 23-44 and 45-65 for the female. Each of the groups was further subdivided into two subgroups based on their smoking habit: smoker and nonsmoker.

This article was accepted: 5 October 2009
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All collected data was recorded and analyzed using the SPSS for Windows Version 14.0. The spirometric values (FVC and FEV_1) were regressed against the independent variables of age, standing height, and weight. Ventilatory function may be expressed as a linear function of age, height, and weight, as indicated in the following equation:

Ventilatory function = $b_0 + (b_1 \times age) + (b_2 \times height) + (b_3 \times weight)$

The main objective of the statistical analyses was to estimate the constant term b_0, the regression coefficients b_1, b_2, and b_3.

RESULTS

Originally, 1071 subjects (age ranging from 10-78 years) participated in this study. They consisted of the Malay, Chinese, Dayak, and Indian ethnicity. However, after excluding the 52 subjects whose questionnaire was not completed; 122 subjects who showed symptoms of cough, phlegm, wheeze, and breathlessness; subjects above the age of 60 years; and 28 subjects of Indian ethnicity (because of insufficient numbers obtained when they were divided into subgroups); we were left with 869 subjects which were then investigated for predicted lung function value standard (Table I).

Table I

In males, the average FVC among the Malays (294), Chinese (89), and Dayaks (81) are 3333.10 mL, 3511.24 mL, and 2961.73 m, respectively; while the average FEV_1 are 3088.44 mL, 3160.34 mL, and 2722.47 mL respectively (Table II).

In females, the average FVC among the Malays (199), Chinese (130), and Dayaks (76) were 2195.18 mL, 2494.23 mL, and 2222.37 mL, respectively; while the average FEV_1 values are 1944.07 mL, 2287.62 mL, and 2049.21 mL, respectively (Table II).

Table II

Regression coefficient and analysis of FVC and FEV_1 against age, height, and weight were conducted separately for both males and females in each of the ethnic groups (smoker and nonsmokers differentiated). A total of 12 formulae each was worked out for FVC and FEV_1, respectively (showed below).

PREDICTION FORMULAE FOR MALE

FVC prediction formulae for nonsmoker male Malays

Sub group		Prediction formula
1) 10-19	(N=94)	FVC = -2393.233 + 154.706 (Age) + 17.970 (Height) + 5.108 (Weight)
2) 20-24	(N=65)	FVC = -1575.508 + 17.135 (Age) + 39.272 (Height) - 25.595 (Weight)
3) 25-44	(N=24)	FVC = -4851.439 + 4.946 (Age) + 42.269 (Height) + 10.388 (Weight)
4) 45-60	(N=17)	FVC = 14822.717 - 73.212 (Age) - 55.236 (Height) + 7.014 (Weight)

FVC prediction formulae for smoker male Malays

Sub group		Prediction formula
5) 10-19	(N=18)	FVC = -1273.401 + 212.409 (Age) - 18.194 (Height) + 75.252 (Weight)
6) 20-24	(N=42)	FVC = -13098.827 - 229.325 (Age) + 134.093 (Height) - 9.661 (Weight)
7) 25-44	(N=25)	FVC = 8092.711 - 119.702 (Age) + 14.727 (Height) - 47.317 (Weight)
8) 45-60	(N=9)	FVC = 4104.889 + 104.108 (Age) + 52.552 (Height) - 225.188 (Weight)

FVC prediction formulae for nonsmoker male Chinese

Sub group		Prediction formula
9) 10-19	(N=49)	FVC = -1889.987 + 174.306 (Age) + 12.639 (Height) + 11.450 (Weight)
10) 20-24	(N=19)	FVC = 8954.214 - 603.609 (Age) + 33.551 (Height) + 24.523 (Weight)
11) 45-60	(N=9)	FVC = -3537.591 + 139.236 (Age) + 0.323 (Height) + 7.478 (Weight)

FVC prediction formulae for nonsmoker male Dayaks

Sub group		Prediction formula
12) 10-19	(N=22)	FVC = -842.219 + 138.036 (Age) + 0. 749 (Height) + 32.247 (Weight)
13) 20-24	(N=12)	FVC = -13883.784 - 283.660 (Age) + 143.204 (Height) - 2.603 (Weight)
14) 25-44	(N=15)	FVC = -1335.165 + 2.785 (Age) + 24.079 (Height) - 1.570 (Weight)

FVC prediction formulae for smoker male Dayaks

Sub group		Prediction formula
15) 25-44	(N=10)	FVC = 10523.418 - 29.405 (Age) - 42.902 (Height) + 2.342 (Weight)

FEV_1 prediction formulae for nonsmoker male Malays

Sub group		Prediction formula
1) 10-19	(N=94)	FEV_1 = -2055.254 + 169.699 (Age) + 12.694 (Height) + 6.747 (Weight)
2) 20-24	(N=65)	FEV_1 = -1233.652 + 8.792 (Age) + 36.052 (Height) - 23.219 (Weight)
3) 25-44	(N=24)	FEV_1 = -1556.477 - 17.949 (Age) + 24.749 (Height) + 11.625 (Weight)
4) 45-60	(N=17)	FEV_1 = 14615.156 - 67.224 (Age) - 54.985 (Height) + 0.999 (Weight)

FEV_1 prediction formulae for smoker male Malays

Sub group		Prediction formula
5) 10-19	(N=18)	FEV_1 = 1793.650 + 301.916 (Age) - 46.544 (Height) + 71.446 (Weight)
6) 20-24	(N=42)	FEV_1 = -13666.483 - 204.361 (Age) + 133.701 (Height) - 11.642 (Weight)
7) 25-44	(N=25)	FEV_1 = 4827.794 - 84.452 (Age) + 20.441 (Height) - 35.985 (Weight)
8) 45-60	(N=9)	FEV_1 = 5157.908 + 56.681 (Age) + 37.620 (Height) - 174.987 (Weight)

FEV_1 prediction formulae for nonsmoker male Chinese

Sub group		Prediction formula
9) 10-19	(N=49)	FEV_1 = -2763.028 + 122.202 (Age) + 21.284 (Height) + 11.415 (Weight)
10) 20-24	(N=19)	FEV_1 = 3517.796 - 453.306 (Age) + 51.249 (Height) + 10.487 (Weight)
11) 45-60	(N=9)	FEV_1 = 1334.754 + 104.919 (Age) - 34.134 (Height) + 34.109 (Weight)

FEV_1 prediction formulae for nonsmoker male Dayaks

Sub group		Prediction formula
12) 10-19	(N=22)	FEV_1 = 794.877 + 170.521 (Age) - 16.687 (Height) + 41.018 (Weight)
13) 20-24	(N=12)	FEV_1 = -6844.844 - 411.404 (Age) + 116.341 (Height) - 4.070 (Weight)
14) 25-44	(N=15)	FEV_1 = -13.539 - 20.140 (Age) + 16.414 (Height) + 5.086 (Weight)

FEV_1 prediction formulae for smoker male Dayaks

Sub group		Prediction formula
15) 25-44	(N=10)	FEV_1 = 11115.307 - 38.183 (Age) - 52.075 (Height) + 16.415 (Weight)

PREDICTION FORMULAE FOR FEMALE

FVC prediction formulae for nonsmoker female Malays

Sub group		Prediction formula
1) 10-17	(N=48)	FVC = -4514.884 + 96.940 (Age) + 40.616 (Height) - 10.590 (Weight)
2) 18-22	(N=42)	FVC = -856.563 - 93.823 (Age) + 33.007 (Height) - 1.532 (Weight)
3) 23-44	(N=78)	FVC = -571.657 - 16.643 (Age) + 19.517 (Height) + 7.236 (Weight)
4) 45-60	(N=24)	FVC = 2374.458 + 4.054 (Age) - 3.609 (Height) - 2.369 (Weight)

FVC prediction formulae for nonsmoker female Chinese

Sub group		Prediction formula
5) 10-17	(N=33)	FVC = 2012.398 + 164.463 (Age) - 17.331 (Height) + 15.917 (Weight)
6) 18-22	(N=32)	FVC = 277.539 - 70.312 (Age) +22.627 (Height) + 4.909 (Weight)
7) 23-44	(N=28)	FVC = - 2453.426 - 15.190 (Age) + 35.258 (Height) + 1.899 (Weight)
8) 45-60	(N=32)	FVC = 4874.258 - 39.126 (Age) - 5.519 (Height) + 5.737 (Weight)

FVC prediction formulae for nonsmoker female Dayaks

Sub group		Prediction formula
9) 10-17	(N=20)	FVC = - 1044.052 + 102.904 (Age) + 13.844 (Height) - 4.099 (Weight)
10) 18-22	(N=10)	FVC = - 1935.025 + 85.262 (Age) + 19.195 (Height) - 1.193 (Weight)
11) 23-44	(N=32)	FVC = - 2593.657 + 0.792 (Age) + 40.625 (Height) - 22.447 (Weight)
12) 45-60	(N=13)	FVC = 1506.165 - 44.107 (Age) + 17.843 (Height) + 1.603 (Weight)

FEV_1 prediction formulae for nonsmoker female Malays

Sub group		Prediction formula
1) 10-17	(N=48)	FEV_1 = -1870.379 + 146.149 (Age) + 14.256 (Height) + 0.249 (Weight)
2) 18-22	(N=42)	FEV_1 = -705.344 - 81.786 (Age) + 24.477 (Height) + 9.052 (Weight)
3) 23-44	(N=78)	FEV_1 = -679.085 - 10.477 (Age) + 17.554 (Height) + 6.491 (Weight)
4) 45-60	(N=24)	FEV_1 = 3129.672 + 0. 338 (Age) - 7.534 (Height) - 4.223 (Weight)

FEV_1 prediction formulae for nonsmoker female Chinese

Sub group		Prediction formula
5) 10-17	(N=33)	FEV_1 = 166.032 + 96.666 (Age) + 0. 830 (Height) + 11.907 (Weight)
6) 18-22	(N=32)	FEV_1 = 661.889 - 81.19053.180 (Age) + 20.469 (Height) + 4.453 (Weight)
7) 23-44	(N=28)	FEV_1 = -1973.624 - 16.428 (Age) + 31.732 (Height) + 0.622 (Weight)
8) 45-60	(N=32)	FEV_1 = 3799.956 - 34.778 (Age) - 3.149 (Height) + 9.366 (Weight)

FEV_1 prediction formulae for nonsmoker female Dayaks

Sub group		Prediction formula
9) 10-17	(N=20)	FEV_1 = - 1946.827 + 59.439 Age) + 22.389 (Height) - 3.020 (Weight)
10) 18-22	(N=10)	FEV_1 = -3404.205 + 61.180 (Age) + 29.954 (Height) – 0.099 (Weight)
11) 23-44	(N=32)	FEV_1 = -2472.006 + 1.798 (Age) + 39.418 (Height) - 24.232 (Weight)
12) 45-60	(N=13)	FEV_1 = -591.045 - 21.893 (Age) + 23.336 (Height) - 0.275 (Weight)

We were unable to obtain the predicted formulae for the following groups/subgroups due to nil or insufficient number of subjects: male Chinese nonsmoker of 25-44 years of age; male Dayak nonsmoker of 45-60 years of age; female Dayak nonsmoker of 20-24 years of age; all subgroups in male Chinese smoker; male Dayak smoker of all subgroup except for the 25-44 years of age; and female smoker in all the ethnic group.

The average age, height, and weight of the subgroup were calculated to compare the predicted ventilatory values (Table III).

Effect of Smoking

Lung function (for FVC and FEV_1, respectively) was compared between nonsmoker and smoker by substituting the average age, height, and weight to the predicted formula (Table IV).

DISCUSSION

The Indian ethnic participants were excluded because of insufficient numbers obtained when they were divided into subgroups. The shortcoming of participant of Indian origin is in accordance with the ethnic composition of Sarawak population i.e., 3,851 Indians among 2,009,893 total population of Sarawak or 0.2%[31]. The highest FVC value is obtained in the 20-24 years of age subgroup, followed by the 25-44, 45-60 and then the 10-19 years of age. The highest FEV_1 value is obtained in the 20-24 years of age subgroup, followed by the 45-60, 10-19, and then the 25-44 years of age (Table IV). In the present study, the peak value for lung functions obtained in the group of 20-24 years of age (for male) and in the group of 18-22 years (for female) is in agreement with Cotes[28].

Regardless of smoking habits, in males, the average FVC and FEV_1 is highest in Chinese 3511.24; 3160.34 followed by Malays 3333.1; 3084.44, and then Dayaks 2961.73; 2722.47, respectively; in females, the order goes from Chinese 2494.23; 2287.23 to Dayaks 2222.37; 2049.21 and then Malays 2195.18; 1944.07 (Table II). These results are in similar with those of Azizi and Henry[7] who reported higher FVC value (for children) in Chinese, followed by Malay and the Indians.

Our results for FVC and FEV_1 in male (non-smokers and smokers, respectively) of all age group are lower compared to the Americans,[13] Europeans,[14-16] and Africans[17,18]. This difference could be due to better height and Body Surface Area of their participants compared to ours. However, due to the non-availability of results pertaining to lung functions test for the population of Sarawak (Malaysia), we are unable to make further comparison of our results.

In this study, data were analyzed for participants who are free of respiratory symptoms. The effect of smoking was observed in Malay males group 10-19 years of age as they had lower lung function compared to the *non-smokers*. According to Gold *et al*,[32] cigarette smoking is associated with 0.20% slower lung function growth in boys during adolescents. This explains the lower lung function value for the male smoker compared to the male nonsmoker in subgroup of 10 to 19 years old.

In contrast, however, the work of Ashford found that FEV_1 and FVC predicted value for coal miners (male of 18 years of age) are slightly higher for the smokers than the nonsmokers[33]. Similar comparison for FEV_1 is seen in both male Malay and Dayak smokers of 20 years of age, where higher predicted value was obtained for the smokers compared to the non-smokers.

Table I: Composition of participants analyzed to get predicted formula by ethnic, gender, and habit (Total = 854)

Malays			Chinese			Dayaks		
Male		Female	Male		Female	Male		Female
NS	S	NS	NS	S	NS	S	NS	NS
200	94	192	78	11	125	56	25	73

NS: Non-smoker; S: Smoker

Table II: Average of FVC and FEV_1 in mL

	Malay		Chinese		Dayak	
	Male (N=294)	Female (N=199)	Male (N=89)	Female (N=130)	Male (N=81)	Female (N=76)
FVC	3333.1	2195.18	3511.24	2494.23	2961.73	2222.37
FEV_1	3088.44	1944.07	3160.34	2287.23	2722.47	2049.21

Table III: Average of age, height, and weight (Male)

Subgroup	Age (year)	Height (cm)	Weight (kg)
10 to 19 (N= 316)	13.84	152.17	48.18
20 to 24 (N= 211)	21.32	166.41	60.83
25 to 44 (N= 220)	34.56	159.23	63.57
45 to 60 (N=122)	50.38	158.71	64.9

Table IV: Predicted values of FVC and FEV_1 for male

		Average of			Predicted FVC		Predicted FEV_1		FEV_1/FVC		ESLF
Ethnic	Subgroup	Age (year)	Height (cm)	Weight (kg)	NS (mL)	S (mL)	NS (mL)	S (mL)	NS (%)	S (%)	
Malay	10 to 19	13.84	152.17	48.18	2728.50	2523.40	2550.10	2331.84	93%	92%	↓
	20 to 24	21.32	166.41	60.83	3768.12	3738.70	3728.24	3517.54	99%	94%	↓
	25 to 44	34.56	159.23	63.57	2710.35	3292.85	2502.99	2874.70	93%	87%	↑
	45 to 60	50.38	158.71	64.9	2822.10	3075.68	2566.58	2627.51	91%	85%	↑
Chinese	10 to 19	13.84	152.17	48.18	2997.35	-	2717.01	-	91%	-	-
	20 to 24	21.32	166.41	60.83	3160.23	-	3019.58	-	96%	-	-
	45 to 60	50.38	158.71	64.9	4013.70	-	3416.84	-	85%	-	-
Dayak	10 to 19	13.84	152.17	48.18	2735.84	-	2591.87	-	95%	-	-
	20 to 24	21.32	166.41	60.83	3740.82	-	3496.75	-	93%	-	-
	25 to 44	34.56	159.23	63.57	2495.38	2824.78	2227.34	2547.30	89%	90%	↑

NS: Nonsmoker, S: Smoker, ESLF: Effect of smoking on lung function, ↓ : Decrease, ↑ : Increase

The pattern of results give the impression that individuals (the Malay and Dayak in this study) who smoke but remain asymptomatic, have certain morphologic advantages over those who do not smoke the same as Ferris's *et al* explained in their report study on subjects who smoke at the early ages[34]. This impression, however, does not apply to Chinese male smokers who show less FVC and FEV_1 values compared to their non-smokers counterpart.

Male Malay smokers in the group of 25-44 and 45-60 years of age have higher value of FVC and FEV_1 then the nonsmoker, however, they have lower FEV_1/FVC ratio (Table IV).

ACKNOWLEDGEMENT

This study was supported by the short-term grant provided by UNIMAS Project Number 1(117)/501/04(238) dated 11 December 2004. The authors thank Prof. Mohd Syafiq Abdullah who allowed laboratory staff to accompany the team to various locations. The authors are grateful to all the staff for participating in the study. The authors are indebted to Mdm. Resni Mona, Head of Publication Division, Unimas, for editing the article.

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