PREDICTION NOMOGRAMS FOR LUNG FUNCTION MEASUREMENTS IN ADULT CHINESE

By J. L. Da Costa and B. K. Goh

SYNOPSIS

Increasing utilization of lung function testing in the diagnosis of respiratory disease has made it pertinent to make available combined prediction nomograms for the various parameters of lung function. This paper presents lung function data on 207 normal Chinese adults. Combined prediction nomograms were derived from regression equations enabling rapid derivation of normal values for the lung volumes in adult Chinese of both sexes. Comparison of the present results with those of other studies has shown that lung volumes in Asians and Africans are considerably lower than in Caucasians. It is therefore important to use local standards of normality when assessing the results of lung function studies.

Although there have been many studies of normal lung function in adult Caucasians (Baldwin *et al*, 1948; Needham *et al*, 1954; Goldman and Becklake, 1959; Kory *et al*, 1961; Berglund *et al*, 1963; Grimby and Söderholm, 1963 and Boren *et al*, 1966), few detailed reports have been published concerning African (Johannsen and Erasmus, 1968) and Asian (Rao *et al*, 1961; Wu and Yang, 1962; Poh and Chia, 1969 and Da Costa, 1971) subjects. Increasing recognition of the value of lung function tests in respiratory disease and their frequent usage in respiratory medicine, has made it pertinent to simplify the determination of normal lung function measurements from existing regression equations by deriving combined prediction nomograms. However, to our knowledge, no such detailed nomograms are available at present.

This paper presents lung function data with combined prediction nomograms for the various lung function measurements in normal adult Chinese of both sexes thus enabling rapid and convenient derivation of normal values.

MATERIALS AND METHODS

Two hundred and seven Chinese subjects (134 males and 73 females) aged between 20 and 66 years were investigated. 75% were born in Singapore, the rest being China-born. The subjects consisted of hospital employees, medical students, doctors, nurses and patients who did not suffer from cardiac or respiratory illnesses. Chest roentgenograms in all were considered normal. All the females were non-smokers, while 30% of the males were light smokers (smoking less than 15 cigarettes/day). Age was recorded to the nearest year; height measured with the subject barefooted to the nearest quarter of an inch, while weight (in light street clothes) was recorded to the nearest pound. The vital capacity (VC), inspiratory capacity (IC), expiratory reserve volume (ERV), forced vital capacity in one second (FEV_1), and forced vital capacity (FVC) were measured in triplicate (the highest value for VC, FEV_1 and FVC being accepted) using a 9 litre Godart closed circuit spirometer. The functional residual capacity (FRC) was measured in duplicate using the closed circuit helium dilution method of Meneely and Kaltreider (1949). The total lung capacity (TLC) and residual volume (RV) were calculated by adding the IC to the FRC, and subtracting the ERV from the FRC, respectively.

RESULTS

Table I presents the mean values, standard deviations (SD) and coefficients of variation for the physical characteristics and each of the physiological measurements of the subjects.

An electronic computer (Central Data Corp. 3600) was used to develop a correlation matrix (Table II) based on the variables measured. Regression equations on age, height and weight were calculated for the seven variables (FEV_1, FVC, FRC, RV, TLC, RV/TLC %, and VC) by a stepwise regression procedure* (Table III). The independent variables age, height and weight were added one at a time, the one producing the greatest reduction in residual variance being added at each step.

* The BMD 02R programme (version of 2nd June 1964) of the Health Services Computer Facility, UCLA, was used for this procedure.

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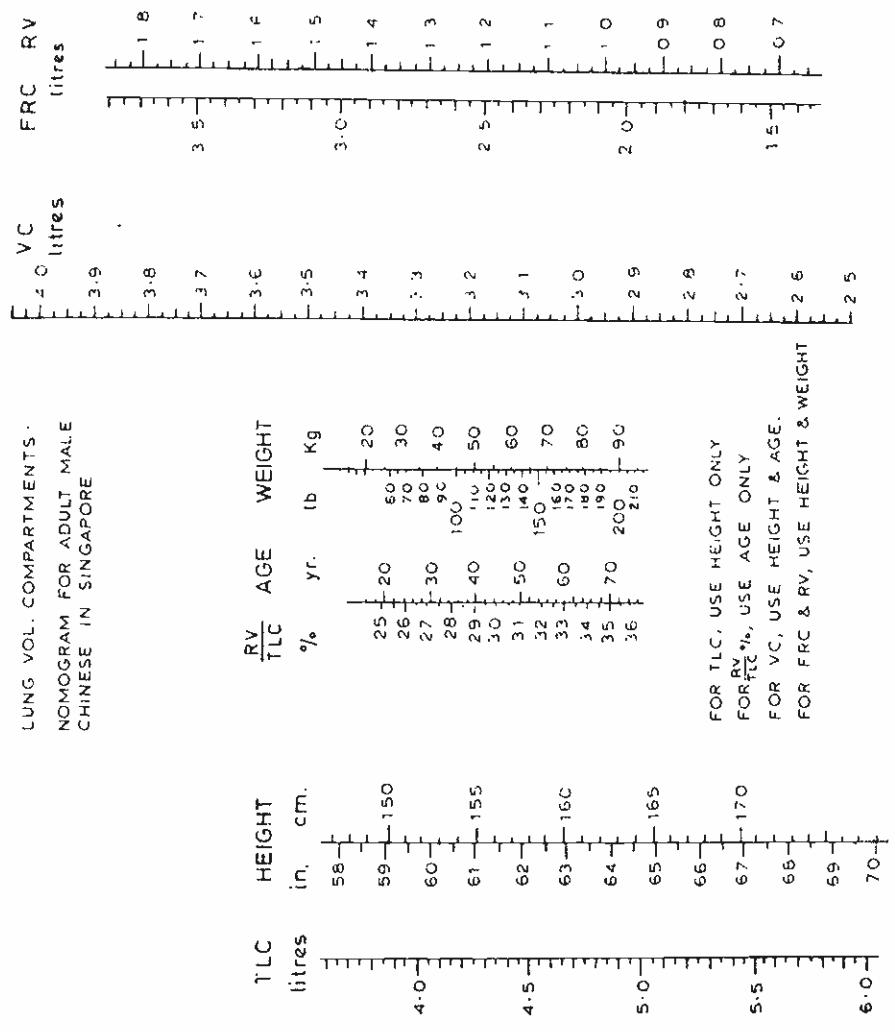
LUNG VOL. COMPARTMENTS.
NOMOGRAM FOR ADULT MALE
CHINESE IN SINGAPORE
VC litres
FRC RV litres
RV/TLC % AGE yr. WEIGHT lb Kg
TLC litres
HEIGHT in. cm.
FOR TLC, USE HEIGHT ONLY
FOR RV/TLC %, USE AGE ONLY
FOR VC, USE HEIGHT & AGE.
FOR FRC & RV, USE HEIGHT & WEIGHT

Fig. 1(b).

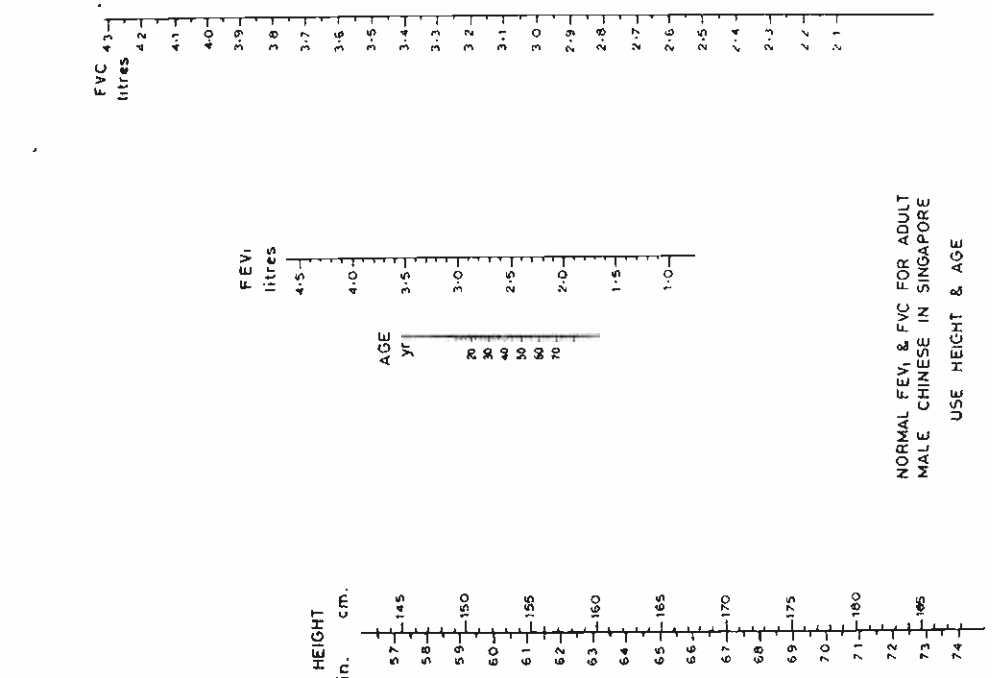
FVC litres
FEV1 litres
AGE yr
HEIGHT in. cm.
NORMAL FEV1 & FVC FOR ADULT
MALE CHINESE IN SINGAPORE
USE HEIGHT & AGE

Fig. 1(a).

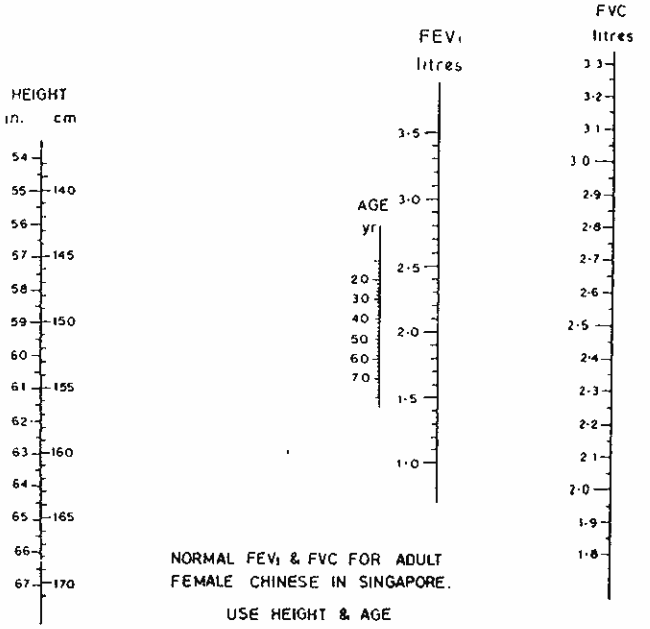

Fig. 2(a).

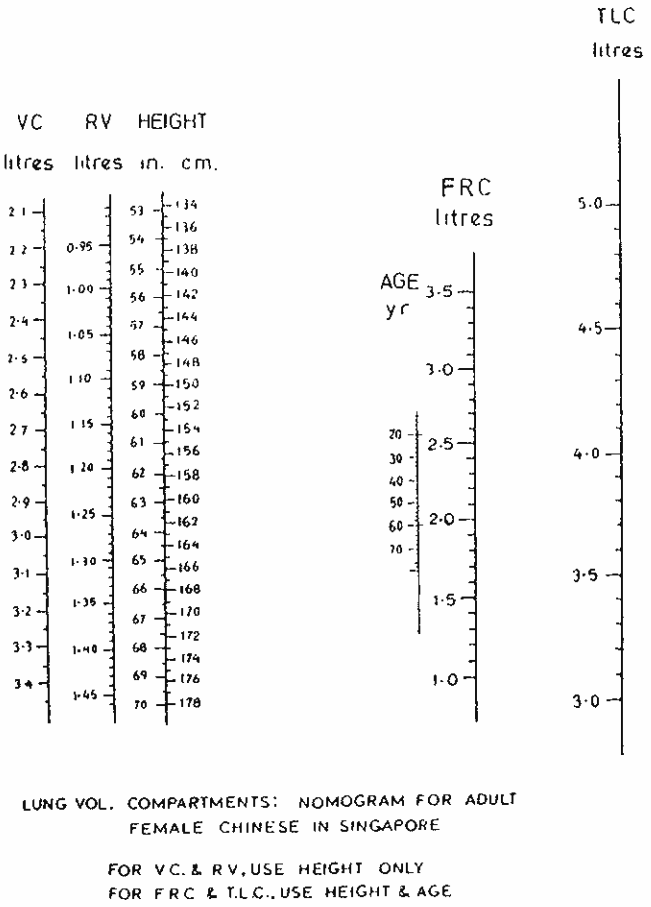

Fig. 2(b).

TABLE I

PHYSICAL CHARACTERISTICS AND LUNG FUNCTION DATA IN THE MALE AND FEMALE SUBJECTS: MEAN VALUES, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION

Measurement		MALES				FEMALES			
		No. of Subjects	Mean Value	Standard Deviation	Coeff. of Variation	No. of Subjects	Mean Value	Standard Deviation	Coeff. of Variation
Age	(yr.)	134	37·3	12·6	33	73	33·2	9·7	29
Height	(in.)	134	65·2	2·1	3	73	61·6	2·7	4
	(cm.)		165·6	5·3			156·5	6.9	
Weight	(lb.)	134	129·0	18·4	14	73	113·3	20·2	18
	(kg.)		58·6	8·4			51·4	9·2	
FEV_1	(ml.)	134	2950	457	16	73	2300	351	15
FVC	(ml.)	134	3620	533	15	73	2760	435	16
VC	(ml.)	91	3610	566	16	68	2765	443	16
FRC	(ml.)	91	2935	471	16	68	2345	440	19
RV	(ml.)	91	1455	360	25	68	1190	314	26
TLC	(ml.)	91	5060	655	13	68	3950	609	15
RV/TLC	(%)	91	28·7	6·0	21	68	30·0	5·9	20

Details for individual subjects as well as the mean values and standard deviations tabulated by 5-year age groups may be obtained from the author.

TABLE II

PHYSICAL DATA AND LUNG FUNCTION MEASUREMENTS IN MALE AND FEMALE CHINESE SUBJECTS: CORRELATION COEFFICIENTS

Measurements	Age	Ht	Wt	FEV_1	FVC	FRC	RV	TLC	RV/TLC	VC
Male Subjects:										
Age	1·00									
Ht	0·38	1·00								
Wt	—	0·41	1·00							
FEV_1	0·64	0·51	—	1·00						
FVC	0·40	0·50	0·29	0·84	1·00					
FRC	—	0·47	—	0·40	0·48	1·00				
RV	—	0·34	—	—	—	0·71	1·00			
TLC	0·33	0·56	—	0·69	0·79	0·76	0·51	1·00		
RV/TLC	0·37	—	—	-0·45	0·50	0·34	0·83	—	1·00	
VC	-0·42	0·43	-	0·76	0·89	0·38	-	0·78	-0·58	1·00
Female Subjects:										
Age	1·00									
Ht	—	1·00								
Wt	—	0·44	1·00							
FEV_1	−0·53	0·40	—	1·00						
FVC	—	0·46	0·31	0·86	1·00					
FRC	−0·42	0·34	—	0·54	0·59	1·00				
RV	—	—	—	—	—	0·85	1·00			
TLC	-0·34	0·45	—	0·73	0·86	0·87	0·71	1·00		
RV/TLC	—	—	—	-0·32	0·34	0·45	0·78	—	1·00	
VC	−0·32	0·44	—	0·86	0·99	0·60	—	0·87	−0·34	1·00

All the correlation coefficients are significant at the 1% level.

Key:
— = Correlation coefficient not significant ($p > 0·01$).
Ht = Height.
Wt = Weight.

TABLE III

REGRESSION EQUATIONS USED FOR DERIVING NOMOGRAMS FOR THE LUNG FUNCTION MEASUREMENTS IN MALE AND FEMALE CHINESE SUBJECTS.

Measurement	Sex	REGRESSION COEFFICIENTS			Constant	Multiple Correlation Coefficient (R)	Standard Error of Estimate (SEE)
		Age yr.	Height cm (in)	Weight kg (lb)			
VC, L	M	-0.0176	+0.0380 (+0.0965)		-1.999	0.549	0.478
	F		+0.0298 (+0.0756)		-1.873	0.436	0.401
FRC, L	M		+0.0608 (+0.1544)	-0.0258 (-0.0117)	-5.586	0.631	0.370
	F	-0.0174	+0.0166 (+0.0422)		+0.326	0.481	0.392
RV, L	M		+0.0328 (+0.0835)	-0.0130 (-0.0059)	-3.209	0.439	0.327
	F		+0.0124 (+0.0314)		-0.740	0.255	0.306
TLC, L	M		+0.0787 (+0.1998)		-7.934	0.564	0.544
	F	-0.0163	+0.0365 (+0.0926)		-1.203	0.507	0.533
RV/TLC, %[1]	M	+0.1960			+21.25	0.368	5.626
FEV_1, L	M	-0.0189	+0.0267 (+0.0678)		-0.774	0.697	0.329
	F	-0.0175	+0.0170 (+0.0431)		+0.232	0.625	0.278
FVC, L	M	-0.0105	+0.0409 (+0.1038)		-2.761	0.548	0.449
	F	-0.0101	+0.0271 (+0.0689)		-1.141	0.510	0.379

[1] The regression equation for females is not tabulated because RV/TLC % did not correlate significantly at the 5% level with either age, height or weight.

TABLE IV

COMPARISON OF PREDICTED VALUES FOR THE LUNG VOLUMES ACCORDING TO VARIOUS WORKERS IN A 35-YEAR-OLD MALE 170 CM. TALL AND WEIGHING 60 KG.

Investigator		Original Case Material	FEV, L (SEE)	VC, L (SEE)	FRC, L (SEE)	RV, L (SEE)	TLC, L (SEE)	RV/TLC, % (SEE)
Berglund *et al* Grimby and Söderholm	1963*	Swedish	4·06 (0·50)	5·14 (0·50)	3·77 (0·56)	1·87 (0·38)	7·08 (0·67)	27 (4·3)
Needham *et al*	1954*	English	— —	4·64 (0·44)	3·66 (0·59)	2·26 (0·41)	6·67 (0·68)	31 (4·4)
Kory *et al* Boren *et al*	1961 † 1966	American	3·72 (0·52)	4·47 (0·53)	2·50 (0·63)	1·39 (0·53)	5·96 (0·87)	24 (6·3)
Goldman and Becklake	1959	S. African (Caucasians)	— —	4·46 (0·49)	3·48 (0·62)	1·74 (0·39)	6·29 (0·65)	29 (4·8)
Johannsen and Erasmus	1968*	Bantu	3·01 (0·42)	3·89 (0·47)	2·58 (0·56)	1.28 (0·46)	5·18 (0·67)	26 (7·3)
Wu and Yang	1962‡	Chinese (Taiwanese)	—	4·03	—	—	5·71	—
Milledge	1965	S. Indians	—	3·44	—	—	—	—
Present Author	1971	Chinese (Singaporean)	3·11 (0·33)	3·84 (0·48)	3·20 (0·37)	1·59 (0·33)	5·44 (0.54)	28 (5·6)

Lung volumes are expressed at BTPS (with the author's standard error of the estimate, if available, in parenthesis) in a sitting position, unless otherwise stated.

*BTPS correction factor applied.

†FEV_1 and VC in standing position, while the other measurements are for a semirecumbent position.

‡Lung volumes in standing position.

TABLE V

COMPARISON OF PREDICTED VALUES FOR THE LUNG VOLUMES ACCORDING TO VARIOUS WORKERS IN A 35-YEAR-OLD FEMALE 156 CM. TALL AND WEIGHING 52 KG.

Investigator		Original Case Material	FEV_1, L (SEE)	VC, L (SEE)	FRC, L (SEE)	RV, L (SEE)	TLC, L (SEE)	RV/TLC, % (SEE)
Needham *et al*	1954*	English	— —	3·61 (0·36)	2·53 (0·45)	1·67 (0·36)	4·64 (0·54)	34 (5·4)
Berglund *et al* Grimby and Söderholm	1963*	Swedish	2·95 (0·36)	3·50 (0·40)	2·26 (0·41)	1·21 (0·32)	4·59 (0·48)	24 (5·5)
Goldman and Becklake	1959	S. African (Caucasian)	—	3·12 (0·42)	2·64 (0·46)	1·41 (0·37)	4·55 (0·53)	31 (5·7)
Kory *et al*	1965†	American	2·77 (0·33)	3·08 (0·37)	— —	— —	— —	— —
Wu and Yang	1962†	Chinese (Taiwanese)	—	2·78	—	—	3·94	—
Johannsen and Erasmus	1968*	Bantu	2·19 (0·32)	2·68 (0·32)	2·01 (0·38)	1·24 (0·33)	3·94 (0·46)	31 (6·4)
Present Author	1971	Chinese (Singaporean)	2·27 (0·28)	2·77 (0·40)	1·55 (0·39)	1·19 (0·31)	3·92 (0·53)	30

Lung volumes are expressed at BTPS (with the author's standard error of the estimate, if available, in parenthesis) in a sitting position unless otherwise stated.

*BTPS correction factor applied.

†Lung volumes in standing position.

The procedure was terminated when no significant reduction was obtained on adding the variable. For most measurements adding either one or two independent variables sufficed. However, in 3 instances (RV and RV/TLC% in males, and FVC in females) addition of all three independent variables produced significant reduction in residual variance (Da Costa, 1971). As a nomogram can only be constructed with one or two variables, regression equations utilizing only the first two independent variables were used in these instances. The differences between the multiple correlation coefficients and standard errors of estimate in the two regression equations in each of these instances respectively, were however not great.

Combined prediction nomograms [Figs. 1(*a*), (*b*) and 2(*a*), (*b*)] for both males and females were then constructed from the regression equations so that the values for the various lung function measurements could be read off directly. The nomogram values did not differ by more than 2% when compared to the respective values calculated from the regression equations.

DISCUSSION

Previous studies of the VC in Asian (Wu and Yang, 1962 and Milledge, 1965) and African (Johannsen and Erasmus, 1968) population groups showed that it was invariably lower than in Caucasian subjects even after allowing for the effects of variations in age, height and weight. Comparison of the predicted values for the various lung compartments according to various authors (Tables IV and V) show that Asian and African subjects have consistently lower values in all the measurements except the RV/TLC ratio. The greatest differences were found on using formulae based on Caucasian subject material (Needham *et al*, 1954; Berglund *et al*, 1963 and Grimby and Söderholm, 1963) the VC, FRC and TLC being about 20-25% greater than the present author's figures.

It is likely that genetic and racial factors affecting body build play an important part in the discrepancy between lung function measurements in Caucasian and non-Caucasian subjects. Smilie and Augustine (1962) postulated that a smaller trunk length: limb ratio in Negroes could be a partial explanation. However, this has not been confirmed and similar studies in Asians have not been published.

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