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Lung elastic recoil in normal young adult Chinese compared with Caucasians

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Lung elastic recoil in normal young adult Chinese compared with Caucasians. C-C. Chan, T-H. Cheong, S-C. Poh, Y-T. Wang. ©ERS Journals Ltd 1995.
ABSTRACT: Chinese people have smaller total lung capacity (TLC) compared with Caucasians of similar age, sex and height. One possible reason would be a higher lung elastic recoil in Chinese. Most published values for lung elastic recoil *viz* static lung compliance (CLst), shape constant K, and maximal static transpulmonary pressure (PLmax) have been from Caucasian subjects. The aim of our study was to obtain values for lung elastic recoil in normal young adult Chinese subjects.

Static expiratory pressure-volume (P-V) curves were studied in 22 healthy Chinese subjects (12 males and 10 females). The P-V curve was fitted using an iterative least mean squares regression on a computer, according to an exponential equation: $V=A - Be^{-KP}$, where V is lung volume, P is transpulmonary pressure, and A, B and K are constants.

Mean values±SD for K, CLst and PLmax were 0.12±0.04, 230±103 ml·cmH$_2$O^{-1} and 27.5±7.5 cmH$_2$O, respectively. The values of CLst and K were similar to that of normal Caucasian subjects, whereas values of PLmax were lower. We attributed the lower PLmax partly to weaker inspiratory muscles in Chinese compared with Caucasians.

We conclude that lung elastic recoil in normal young adult Chinese is similar to that of healthy young adult Caucasians. Hence, lung elasticity is unlikely to explain the racial differences in static lung volumes.
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Race is an important determinant of lung function [1]. When compared with Caucasians of European descent, values for other races usually show smaller static lung volumes [2] and lower forced expiratory flow rates, but similar or higher forced expiratory volume in one second/forced vital capacity (FEV$_1$/FVC) ratio [3]. One possible reason would be a higher lung elastic recoil in non-Caucasians. The elasticity or retractile force of the lung has been studied previously in normal Caucasian subjects [4–6]. Gibson *et al.* [5] suggested that the exponential constant K, an index of lung elastic recoil, is independent of species. He based this on the finding that values of K in normal subjects were similar to those in dog and monkey lungs and lobes [7]. This would imply that K was independent of race. We studied the static lung compliance (CLst), K, and maximum static transpulmonary pressure (PLmax) in young adult Chinese subjects to obtain normal values, and compared them with established normal Caucasian values.

To the best of our knowledge, there is only one previous published study of normal values for lung compliance in Chinese subjects [8]. Static lung compliance and PLmax were studied in that paper, which was written in the Chinese language. The CLst does not adequately describe the nonlinear behaviour of lungs. It only describes the slope of the pressure-volume (P-V) curve during the initial 500 ml above functional residual capacity (FRC). It also depends on sex and lung size. The PLmax is an index both of lung and chest wall recoil, as well as inspiratory muscle strength. The shape constant, K, reflects the rate at which the P-V curve changes its slope and is independent of sex [4–6], and lung size [5, 6], and insensitive to measurement technique [6]. It is, therefore, a better index of lung elastic recoil. No data on K were available from that study. We studied K, CLst and PLmax in 22 healthy young adult Chinese subjects.

Methods

Static expiratory P-V curves were obtained in 22 normal Chinese subjects (12 males and 10 females) aged 22–38 yrs (mean±SD 29±4 yrs), all of whom were lifelong nonsmokers. These subjects were all doctors working in the hospital. Their anthropometric data and lung volumes are as shown in table 1.

Static lung volumes were determined before the start of the P-V study. For each subject, the FRC was determined by a closed circuit technique using a nitrogen washout method (CAD/Net system 1070, Medical Graphics

Table 1. – Anthropometric data and lung volumes of all subjects (n=22)

Age yrs	Height cm	Weight kg	TLC *l*	TLC pred (Caucasian) *l*	TLC % pred (Caucasian)	TLC% pred (Chinese)
29 (4)	166 (9.7)	59.0 (12.6)	5.3 (1.2)	5.7 (1.2)	93 (15)	109 (17)

Data are presented as mean and SD in parenthesis. TLC calculated and percentage predicted TLC were based on predictive equations for Caucasians [9] and Chinese [2]. TLC: total lung capacity.

Corporation, St Paul, MN, USA). During the P-V study, all subjects were studied in the sitting position and care was taken to loosen any tight clothing. Transpulmonary pressure (PL) was measured as the difference between mouth and oesophageal pressure, employing the oesophageal balloon technique of MILIC-EMILI *et al.* [10]. After topical anaesthesia of the nose and pharynx, the oesophageal balloon was passed intranasally into the stomach, and then gradually withdrawn until a negative deflection was present during inspiration. The balloon was then withdrawn another 10 cm and fastened to the nose at that level. The second (gastric) balloon was likewise inserted into the stomach and fixed at that level. Each balloon, which was commercially available (Erich Jaeger, Hoechberg, Germany), was 10 cm long and 3 cm in perimeter. A pressure transducer (MP45-1-871 ±350 cmH_2O, Validyne Corporation, Northridge, CA, USA) was used to measure transpulmonary pressure.

After performing three full inspirations, the subject held his breath at total lung capacity (TLC) with open glottis, whilst maximal static transpulmonary pressure (PLmax) was measured. He then relaxed against a closed airway and was subsequently allowed to exhale in stepwise fashion into a 7 *l* water spirometer (Warren E. Collins Inc., Braintree, MA, USA). The airway was occluded for periods of 1–2 s, during which measurements of static transpulmonary pressure (PL) were made. Lung volume change was obtained simultaneously during expiration from a rotational transducer attached to the wheel of the spirometer. The PL and volume data obtained were recorded on an 8-channel paper recorder (Gould 2800S, Cleveland, OH, USA). Between 5 and 10 deflations were performed, and values of PL and absolute lung volume (V) were plotted between TLC and functional residual capacity (FRC). Gas volumes were corrected for compression and to body temperature, atmospheric pressure and water saturation (BTPS). For each subject, 3–7 sets of deflation P-V data were obtained for analysis, with adequate rest in between. In general, at least two deflation manoeuvres which showed PL at a given V in agreement to ±1 cmH_2O were required for analysis. Individual discrepant curves were ignored.

Mathematical and statistical methods

The curve was fitted using an iterative least mean squares regression on a computer, according to the exponential equation [11]: $V=A - Be^{-KP}$, where A represents the extrapolated volume at infinite pressure, and B is a constant related to the intercept on the volume axis. When PL is zero, the extrapolated volume is A-B. The ratio of B/A% is used to indicate the position of the P-V curve. The exponential constant K reflects the rate at which the P-V curve changes slope, and indicates the shape of the curve. The CLst was obtained by dividing the volume change of 500 ml by the change in PL between FRC and FRC + 500 ml.

Below a certain volume, the P-V curve departs from exponential decay. COLEBATCH *et al.* [11] found that when FRC was lower than 50% TLC, the exponential fitted to FRC often did not represent the data point satisfactorily. Therefore, if FRC was lower than 50% TLC, we used deflation data from TLC to 50% TLC instead of FRC for curve-fitting.

The quality of fit of the exponential equation to the data for each subject was assessed by the standard errors of the coefficients (K, A and B) and the reduction of the original variance (R^2) which was calculated as described previously [12]. An arbitrary R^2 value of 0.96 was chosen, below which the scatter of the points around the line was considered unacceptable [5].

Group data are expressed as mean±SD with the range of values in brackets. Kolmogorov-Smirnov tests confirmed normal distribution of K, CLst, CLst/TLC and PLmax in our subjects. Comparisons between male and female parameters were tested for statistical significance using unpaired Student's t-test. Mann-Whitney rank sum test was used for comparing the position index, B/A, between male and female subjects. Simple correlations were obtained by calculating Pearson's and Spearman's rank correlations as appropriate.

Results

The mean TLC values for females and males were 4.4±0.7 and 6.0±1.0 *l*, respectively. The calculated and percentage predicted TLC from predictive formulae taken for Caucasians [9] and Chinese [2] subjects are shown in table 1. On the whole, the mean actual TLC for all subjects was 5.2±1.2 *l*, which was 8.3% lower than the mean calculated TLC (5.7 *l*) derived from Caucasian predictive formulae [9].

An exponential function could be fitted to the P-V data, with good quality of fit both on visual inspection and in terms of statistical criteria in all but one subject (R^2=0.93). The mean value of R^2 was 0.98, and the mean

Table 2. – Correlations between the variables measured or derived

	K	CLst	CLst/TLC	PLmax	B/A	FRC	TLC	Age	Height
K		0.628	0.869	-0.496	NR	NR	NR	NR	NR
CLst	0.628		0.823	NR	0.644	0.44	0.622	NR	0.477
CLst/TLC	0.869	0.823		-0.426	0.487	NR	NR	NR	NR
PLmax	-0.496	NR	-0.426		NR	NR	NR	NR	NR
B/A	NR	0.644	0.487	NR		NR	NR	NR	0.512

Minus sign denotes negative correlation. All correlations noted were significant ($p<0.05$). NR: no significant correlation; K: shape constant; CLst: static lung compliance; TLC: total lung capacity; PLmax: maximal static transpulmonary pressure; B/A: position index of pressure-volume curve; FRC: functional residual capacity.

within-subject standard errors of the coefficients were 0.016, 0.18 and 0.36 for K, A and B, respectively. The detailed results are as shown in table 2.

The mean values for CLst, K and PLmax were 230±103 ml·cmH$_2$O^{-1} (89–550 ml·cmH$_2$O^{-1}), 0.120±0.040 (0.050–0.189) and 27.5±7.5 cmH$_2$O (10.5–43.0 cmH$_2$O), respectively. There was no statistical difference between male and female values for the measured parameters. The correlations between CLst, K, PLmax, CLst/TLC, B/A, lung volumes, age and height are presented in table 2.

The volume extrapolated to infinite transpulmonary pressure, A, would be expected to be higher than TLC. The mean value for A was 5.7±1.3 *l* (3.8–7.8 *l*). On the average, A was 109% TLC (101–30% TLC).

The index of position of the P-V curve, B/A, was significantly higher in males compared with females ($p=0.005$).

The shape constant, K, in our subjects was not much different from previous published values obtained from normal Caucasian subjects [4–6]. The CLst in our subjects was comparable to the CLst of 90–400 ml·cmH$_2$O^{-1} in normal Caucasian subjects [1]. Using the predictive equations for Caucasians from COLEBATCH *et al.* [4], the mean K % predicted was 97±32 (41–157) (table 3). The mean CLst % predicted was 75±30% (30–163%).

The PLmax of our subjects was lower than the PLmax of 34.5±12.7 (20.0–69.0) cmH$_2$O obtained in 21 healthy Caucasian subjects (15 males and 6 females) of comparable age (29±5 yrs) [13]. However, our patients had lower TLC (5.2±1.2 *l*) compared with the same Caucasian subjects (6.5±1.1 *l*). Of note was the higher mean value of A expressed as a percentage of TLC compared with normal Caucasian subjects (103% TLC, COLEBATCH *et al.* [4]; and 104% TLC, KNUDSON *et al.* [6]). We did not find any significant relationship of K and CLst with age, in contrast to previous findings in normal Caucasians. This was hardly surprising in view of the younger age and narrow age range of our subjects.

Table 3. – Mean data for compliance, CLst and K constant

	CLst ml·cmH$_2$O^{-1}	CLst % pred	K	K % pred
Mean (SD)	230 (103)	75 (30)	0.12 (0.04)	97 (32)

Predictive formulae for Caucasians were from COLEBATCH [4]. For abbreviations see legend to table 2.

Discussion

We found that the values of K and CLst in our subjects were comparable to those of healthy Caucasian subjects. Thus, it seems unlikely that there are racial differences in the elastic properties of the lung. However, as the difference between the actual Caucasian TLC and calculated TLC derived from Caucasian prediction equations was only 8.3%, small differences in CLst and/or K cannot be absolutely discounted. The shape constant, K, in our subjects was better correlated to CLst/TLC than CLst, as would be expected because of volume dependence of the latter. However, CLst/TLC was related to the position index B/A, whereas K was not. Loss of lung recoil is recognized as part of the normal ageing process [12–14]. The shape constant, K, has been shown to increase linearly with age [4–6], but, probably due to the younger age and narrow age range of our subjects, we were unable to demonstrate this relationship. It appears that the shape constant, K, is the best index of lung elasticity in our subjects because it is independent of lung size and position of the P-V curve.

The position index, B/A varies even amongst Caucasian studies and may be dependent on the measurement technique [6]. Therefore, it is difficult to compare our values with those of Caucasians. The B/A in our subjects was significantly higher in males compared with females, which implies that males have a higher lung recoil at the same lung volume. This is not unlike male Caucasian subjects, who tend to have higher lung recoil then their female counterparts of comparable age [12–14]. However, the difference in PLmax was not statistically significant between our male and female subjects.

Our subjects had lower PLmax compared with Caucasian subjects of the same age. Since lung elasticity is similar both in Chinese and Caucasians, as shown by the similar K and CLst values, and assuming that the position of the P-V curve is similar, the lower PLmax may be a reflection of the different extrapulmonary characteristics in our subjects. There may be relative extrapulmonary restriction *viz* weaker inspiratory muscles or decreased chest wall compliance in our subjects compared with Caucasian subjects, resulting in a lower TLC. This was supported by the fact that our maximal volume at infinite transpulmonary pressure, A, was 109% TLC compared with that of COLEBATCH *et al.* (AC) [4], and KNUDSON *et al.* (AK) [6] which were 103% TLC and 104% TLC, respectively. Therefore, our TLC was further from A on the P-V curve than those of Colebatch and Knudson, implying that our subjects could have reached a higher lung volume, that is nearer A, if not for the extrapulmonary restriction. From the results obtained in a previous study, our values for maximal static inspiratory mouth pressure [15] were on the average lower than those of young adult Caucasians [16]. Hence, weaker inspiratory muscle strength can explain, at least in part, the smaller TLC of Chinese subjects.

In addition to extrapulmonary restriction, a lower value of A is another possible explanation for the lower TLC in our subjects. In order to derive the values of A, AC and AK, we first used the predicted equation for TLC from QUANJER [9] and applied it to the anthropometric data of our subjects to get the predicted Caucasian TLC. We found that for similar age, sex and height, the predicted Caucasian TLC was on average 8.3% higher than our subjects. We then calculated the A, AC and AK based on our mean TLC multiplied by 1.085, the mean predicted Caucasian TLC multiplied by 1.025, and the mean predicted Caucasian TLC multiplied by 1.04, respectively. Expressed as a percentage of our TLC, AC and AK were only slightly higher (by 2.5 and 4.1%, respectively) compared with our value for A. Thus, we could not find any difference in the theoretical maximal distensibility of the lungs between Chinese and Caucasians.

We conclude that lung elastic recoil in normal young adult Chinese, as determined by the shape constant, K, and the static lung compliance, CLst, is comparable to that in healthy young adult Caucasians. Lung elasticity is very likely to be independent of race and, hence, is unlikely to account for the racial differences in static lung volumes. Thus, weaker inspiratory muscle strength and, perhaps, a stiffer chest wall may be responsible for the lower TLC in Chinese subjects. As in previous studies, we found that the monoexponential function, $V=A - Be^{-KP}$, describes the pressure-volume characteristics of the lung well, and the shape constant, K, is the best index of lung elasticity.

References

1. Cotes JE. Lung function throughout life: determinants and reference values. *In*: Cotes JE, ed. Lung Function: Assessment and Application in Medicine. 4th edn. Oxford: Blackwell Scientific Publications, 1979; pp. 329–347.
2. Poh SC, Chia M. Respiratory function tests in normal adult Chinese in Singapore. *Singapore Med J* 1969; 10: 265–271.
3. Schwartz DJ, Katz SA, Fegley RW, Tockman MS. Sex and race differences in the development of lung function. *Am Rev Respir Dis* 1988; 138: 1415–1421.
4. Colebatch HJ, Greaves IA, Ng CK. Exponential analysis of elastic recoil and aging in healthy males and females. *J Appl Physiol: Respirat Environ Exercise Physiol* 1979; 47(4): 683–691.
5. Gibson GJ, Pride NB, Davis J, Schroter RC. Exponential description of the static pressure-volume curve of normal and diseased lungs. *Am Rev Respir Dis* 1979; 120: 799–811.
6. Knudson RJ, Kaltenborn WT. Evaluation of lung elastic recoil exponential curve analysis. *Respir Physiol* 1981; 46: 29–42.
7. Glaister DH, Schroter RC, Sudlow MF, Milic-Emili J. Bulk elastic properties of excised lungs and the effect of a transpulmonary pressure gradient. *Respir Physiol* 1973; 17: 347–364.
8. Lin JT. Measurement of P-V curves of the lungs and its use in clinical assessment. *Chung-Hua Chieh Ho Ho Hu Hsi Tsa Chih* 1991; 14(3): 159–161.
9. Quanjer PH, ed. Standardized lung function testing. Report of the Working Party. *Bull Eur Physiopathol Respir* 1983; 19 (Suppl. 5): 1–95.
10. Milic-Emili J, Mead J, Turner JM, Glauser EM. Improved technique for estimating pleural pressure from oesophageal balloons. *J Appl Physiol* 1964; 19: 207–211.
11. Colebatch HJH, Ng CKY, Nikov N. Use of an exponential function for elastic recoil. *J Appl Physiol: Respirat Environ Exercise Physiol* 1979; 46(2): 387–393.
12. Bode FR, Dosman J, Martin RR, Ghezzo H, Macklem PT. Age and sex differences in lung elasticity, and closing capacity in nonsmokers. *J Appl Physiol* 1976; 41(2): 129–135.
13. Gibson GJ, Pride NB, O'Cain C, Quagliato R. Sex and age differences in pulmonary mechanics in normal nonsmoking subjects. *J Appl Physiol* 1976; 41(1): 20–25.
14. Knudson RJ, Clark DF, Kennedy TC, Knudson DE. Effect of aging alone on mechanical properties of the normal adult human lung. *J Appl Physiol: Respirat Environ Exercise Physiol* 1977; 43(6): 1054–1062.
15. Wang YT, Poh SC. Lung function and respiratory muscle strength after propranolol in thyrotoxicosis. *Aust NZ J Med* 1986; 16: 496–500.
16. Leech JA, Ghezzo H, Stevens D, Becklake MR. Respiratory pressures and function in young adults. *Am Rev Respir Dis* 1983; 128: 17–23.