

Lung function in young adults: evidence for differences in the chronological age at which various functions start to decline

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ABSTRACT In order to gather prospective information on the chronological age at which lung functions start to decline, follow-up measurements were carried out on 38 young adults (30 men and eight women) whose respiratory and cardiac function had been studied previously in the course of a survey of high school students. In the 15 subjects who had reached adult height at the time of the first study, only the vital capacity showed no change between studies, while forced expiratory flow rates (FEV₁, MMEF), transfer factor (TLCO) and alveolar volume (VA) all decreased. By contrast, in the 23 subjects who had grown in stature since the previous tests, there was an increase in the slow and forced vital capacity, no consistent change in FEV₁ and MMEF, and a decrease in TLCO. The findings are consistent with the view that the age-related decline does not start at the same chronological age for all lung functions, and suggest that structural changes associated with biological "aging" affect some functions before others. The results also illustrate the inadequacy of predicting values for early adulthood by backward extrapolation from later decades or forward extrapolation from the teens, and underline the need for comprehensive studies to elucidate the pattern of change which accompanies growth, maturation, and early adulthood.

For the most part our concepts of how lung functions "age" have been derived from cross-sectional studies of populations spanning an appropriate age range, usually 20-80 years,¹⁻⁵ with events in early adulthood being assessed by backward extrapolation from later decades or forward extrapolation from the teens.¹⁻⁶ However, a different picture emerges from studies in populations which span the periods of somatic growth, maturing, and aging.⁷⁻⁹ Thus there is gathering evidence^{8,9} that once somatic growth ceases, there is a period when some functions, such as vital capacity,⁷⁻⁹ continue to increase (the consequence, it is believed, of an increase in muscularity particularly of the shoulder girdle⁹), others such as peak flow rate¹⁰ and transfer factor¹¹ remain relatively stable,¹⁰ while yet others such as forced expiratory flow-rates low in the vital capacity decrease.^{8,9} Similar results were reported in a longitudinal study on

a cohort of medical students followed over 10 years.¹²

An opportunity to gather some prospective information on the age-related changes of lung function which occur after somatic growth ceases arose as a result of a previous study we had carried out on the growth of heart and lung function in teenage high school students.⁶ Seven to eight years had elapsed since the previous measurements so that all subjects were now older than 20 years of age. It was, therefore, decided to recall all subjects who could be traced for re-examination with the specific objective of determining the direction and magnitude of changes in lung functions of those subjects who had already attained their adult height at the time of the previous examination.

Methods

The original study had been carried out on a random sample (n=168) stratified for sex, age, and height, of the approximately 1400 students currently attending an inner city high school in

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Montreal.⁶ One hundred and fifteen of the original sample were traced through the last address available in the school records and 18 of these had moved from Montreal; 39 attended for follow-up measurements. One subject who had developed asthma since leaving school was subsequently excluded, leaving 38 in the final analysis. The lung function results of these 38 subjects at the time of the first study were not different from those of the remainder of the original sample of the same sex, age, and height.

Subjects were examined by a respiratory symptom questionnaire, based on the British Medical Research Council questionnaire of 1966, and the following lung function tests: spirometry on a Stead-Wells spirometer, for measurement of inspired vital capacity (VCI), forced expiratory vital capacity (FVC), forced expiratory volume in one second (FEV₁), and maximal mid-expiratory flow rate (MMEF); single breath test for CO diffusion (TLCO) calculated from Krogh's diffusion constant (K) and the alveolar volume (VA). Since our objective was comparison of the individual's results over time, we used exactly the same apparatus, calibrated in exactly the same way, and subjects performed the same number of tests in the same sequence, and followed the same procedures as before.⁶ To assess the possible effect of between-reader differences in spirometry analysis,¹³ the technician who carried out the present tests reanalysed a set of 10 tracings from the original series—the mean and standard deviation of differences for FVC, FEV₁, and MMEF, respectively, 0.00 l (±0.03), 0.00 l (±0.04) and -0.06 l/s (±0.15), were minimal.

For the purposes of data analysis, subjects were divided into those who had not grown in height since the first study (group A: difference in height between tests <2.5 cm) and those who had (group B: difference in height between tests >2.5 cm). This criterion was selected to include the greatest decrease in height recorded (-2 cm) and presumably reflects errors in the measurement of height. Only those subjects who had not changed in height (group A) are relevant to the objective of the present study, which was to record changes in lung function once adult height has been achieved. However, results on subjects who had grown provided a check on procedure and measurement techniques, small changes of which may well have occurred over time despite our efforts to ensure comparability. Mean, standard error and *t* statistic (mean/SE) were calculated for differences in lung functions between studies for groups A and

B separately, and *p* values were multiplied by six, the number of *t* statistics calculated for each group (Bonferroni adjustment). No adjustment was made for interdependence of tests.

Results

Questionnaire data indicated a low prevalence of symptoms evenly distributed between groups A and B. No subjects reported cough, two sputum, five dyspnoea on exertion, and severe wheezing. Two men, one in each group, were currently engaged in occupations with a potential respiratory hazard (machine operator in a yarn mill, construction worker). Somewhat more than half the subjects (9/15 in group A and 11/23 in group B) were current smokers.

Mean changes in the lung functions between the first and second studies are shown for the two groups in table 1. In boys who, for the purposes of the present study, were considered not to have grown between tests (group A) there was on average a small increase in VCI and a small decrease in FVC, MMEF, and VA but these changes were not significant. However FEV₁ and TLCO did show a significant decrease. By contrast, in boys who had grown since the previous measurements (group B), there were significant increases of VCI and FVC of approximately 0.9 while the changes in all other

Table 1 Mean changes in body characteristics and lung functions between first and second studies in subjects who had not grown in height since first study (group A) and subjects who had (group B)

Body characteristics and lung functions	Mean change since first study (range or SE)	
	Group A	Group B
Boys		
	n=11	n=19
Age (yr)	+7.0 (6.4 to 8.8)	+7.9 (6.6 to 7.8)
Height (cm)	+1.5 (-.4 to +2.5)	+7.9 (2.7 to 25.0)
Weight (kg)	+3.4 (-14.0 to +13.8)	+11.4 (-9.4 to 23.0)
VCI (l)	+0.13 (0.12)	+0.89 (0.21)*
FVC (l)	-0.19 (0.10)	+0.90 (0.18)*
FEV ₁ (l)	-0.31 (0.11)*	+0.32 (0.17)
MMEF (l/s)	-0.51 (0.23)	-0.18 (0.65)
TLCO(ml/mm/min)†	-6.4 (1.3)*	-1.1 (2.0)
VA (l)	-0.88 (0.45)	+0.33 (1.3)
Girls		
	n=4	n=4
Age (yr)	+6.9 (6.5 to 7.8)	+7.5 (6.6 to 8.8)
Height (cm)	+0.1 (-1.3 to +.7)	+5.3 (3.0 to 9.5)
Weight (kg)	+2.5 (-.5 to +5.2)	+5.1 (-0.8 to +16.5)
VCI (l)	+0.12 (0.16)	+0.24 (0.18)
FVC (l)	-0.11 (0.11)	+0.07 (0.16)
FEV ₁ (l)	-0.46 (0.09)*	+0.07 (0.16)
MMEF(l/s)	-0.75 (0.10)*	+0.09 (0.31)
TLCO(ml/mm/min)†	-1.8 (2.6)	-5.3 (1.5)
VA (l)	-0.35 (0.29)	+0.06 (0.40)

* <0.05 (calculated using the Bonferroni adjustment, see text).

† To convert from ml STPD mmHg⁻¹ to mmol kPa⁻¹ divide by 0.334.

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Table 2 Lung functions (mean, SA) at the second study with subjects divided into those who had not grown in height (group A) and those who had (group B)

Body characteristics and lung function	Boys		Girls	
	Group A	Group B	Group A	Group B
Number	11	19	4	4
Age (yr)	25.2 (0.39)	22.8 (0.34)	24.6 (1.1)	21.6 (0.25)
Height (cm)	174.8 (1.7)	174.3 (1.8)	159.8 (0.9)	159.8 (1.4)
Weight (kg)	74.3 (3.3)	73.1 (2.2)	54.4 (2.8)	52.8 (3.5)
VCI (l)	4.95 (0.22)	4.92 (0.21)	3.31 (0.23)	3.29 (0.18)
FCV (l)	5.12 (0.21)	5.15 (0.22)	3.37 (0.27)	3.39 (0.19)
FEV ₁ (l)	4.23 (0.19)	4.08 (0.21)	2.55 (0.09)	2.93 (0.18)
MMEF (l/s)	4.56 (0.33)	4.11 (0.25)	2.57 (0.16)	3.44 (0.40)
TLco (ml/mm/min*)	25.5 (1.4)	26.5 (1.4)	17.6 (3.8)	14.8 (0.70)
VA (l)	5.76 (0.94)	5.79 (0.92)	4.17 (0.71)	4.14 (0.40)

* To convert from ml STPD mm Hg⁻¹ to mmol k Pa⁻¹, divide by 0.334

measurements were small and not statistically significant. The pattern of change was similar in the girls.

The numerical data from table 1 are shown graphically in the figure in which measurements for individual subjects at first study are plotted against measurements at second study. For group A (open circles) it is only in the panel for VCI that points are equally distributed about the line of identity; for FVC approximately one-third only lie on or above the line, while for all other panels almost all points fell below the line of identity. The contrast with group B subjects

(solid circles) is evident in all panels including TLco though for this panel both open and closed circles straddle the line of identity; nevertheless the open circles are distributed preferentially below this line. From table 2 it can be seen that at the time of the second study the mean values for the two groups were comparable for the body characteristics usually used to predict lung functions (height and weight) as well as for all the lung functions. In other words, group B subjects, who were first studied at a younger age and who therefore had grown more in height between tests, had become comparable to group A subjects not only in respect of body stature, but also in respect of lung functions.

Discussion

These findings provide further evidence that once adult height is reached, there are differences in the chronological age at which lung functions start to decline, and our findings are compatible with the view that vital capacity remains stable over an age span when forced expiratory flow rates (particularly those dependent on flow at low lung volumes) and the transfer factor have already started to decrease.

The evidence we advance is based on a comparison of the pattern of change over time in one lung function test vis à vis others in individuals identified by an independent characteristic—namely, failure to increase in height

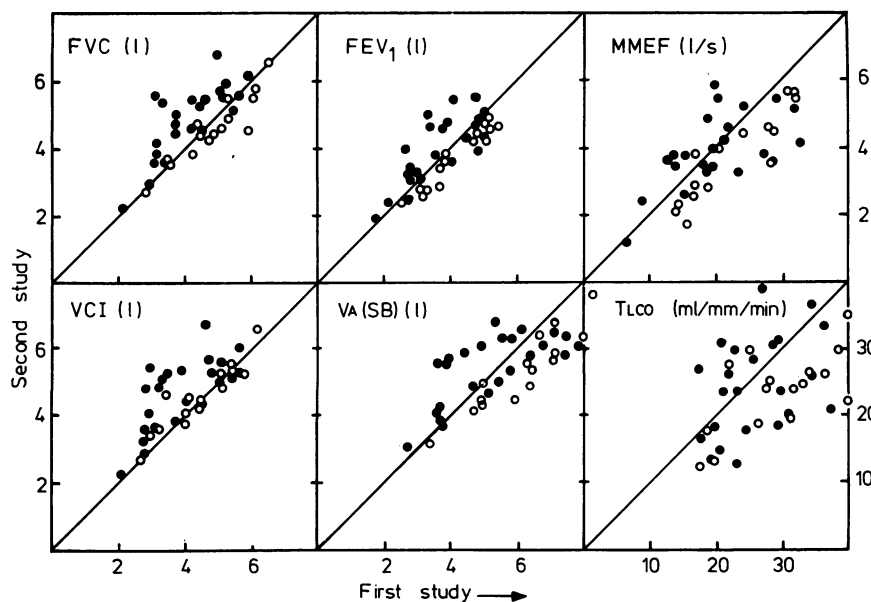


Figure Lung function at the time of the first study and at the time of the second study in subjects who had not grown between studies (group A: open circles) and subjects who had (group B: closed circles).

over the study period (group A). We also confirmed that this pattern was different from that in subjects who grew (group B), thereby diminishing the likelihood that the changes observed were solely the result of unsuspected changes in methodology. Smoking in all likelihood modified the changes over time but since equal proportions in groups A and B were current smokers, between-group differences in pattern of change should be valid. Furthermore, scrutiny of individual results did not reveal obvious differences between smokers and non-smokers. Finally, it is evident that the students we examined were not a planned sample of the group originally studied. However, since we were able to establish that when first examined their lung functions (the characteristics under study) were comparable to those of the original group of the same sex, age, and height, there is no reason to believe that the pattern of growth and maturation of these characteristics (a natural biological event) would have been essentially different in character or even in degree from those of the original sample not re-examined.

We did not show an increase in VC in the early twenties, in keeping with the original nineteenth century data of Hutchinson,¹⁴ as well as with some of the earlier twentieth century data.¹⁵ However, more recent data including two major cross-sectional studies^{8,9} and a recent one of our own concentrating on early adulthood¹⁶ as well as the medical student cohort study,¹² all report a definite increase in this measurement in men (less evident in women) in the early twenties—that is, at an age when presumably somatic height has reached a stable level. This increase, associated with a weight increase, has been attributed to muscular development.⁹ In the present study, we may have missed this trend in the seven to eight years between measurements.

By contrast with the VCI and FVC, the forced expiratory flow rates, FEV₁ and MMEF, showed a decline over the same period of time in our study, an observation in keeping with the reported cross-sectional data.^{8,9,16} However, in these studies as well as in the present study, volume was recorded at the mouth, not using a body plethysmograph, and thus we cannot exclude the possibility of intrathoracic gas compression contributing to, or perhaps accounting entirely for, the observed decline in forced expiratory flow rates, particularly if significant muscular development takes place in the early twenties.¹⁶ Alternatively, the decline may indeed

be attributable to the onset of phenomena associated with biological "aging."

The decline in TLCO we observed is in keeping with the findings in the medical student cohort study,¹² but contrasts with the findings in two cross-sectional studies where age-related changes in TLCO were not evident before the thirties.¹¹ It is more difficult to exclude the influence of technical factors in the measurement of TLCO than, for instance, in the measurement of VC, indeed in the second follow-up of the medical student cohort (average age 28 years) this measurement had again increased.¹² In our study the fall in TLCO was the consequence of a decline in K as well as V_A measured by the single breath helium dilution as part of the measurement. In the absence of plethysmographic measurements, it is not possible to determine whether this decline in V_A represents a true decline in intrathoracic gas volume or, as appears more likely, a decline in communicating lung volume, a possible concomitant of the increase in the level of airway closure known to occur between the teens and the twenties.¹⁸

The present results reinforce the point made previously by ourselves^{1,6} and others^{9,19} that simple linear regressions on age are inaccurate for predicting values for the young adult and highlight the need for further study to define the changes associated with growth and maturation as well as early "aging" of lung functions. In addition because the changes are not the same for all lung functions, the range of measurements for study should be at least as comprehensive as used in our study. Thus lung volume measurements should be included, preferably using body plethysmography, in addition to static and dynamic lung volumes and transfer factors. Indeed the development of accurate prediction formulae for young adulthood has more than theoretical importance not only for routine lung function laboratories where the young and healthy are now far more frequently examined particularly in relation to occupation,⁹ but also because of increasing attention directed to changes in lung function in early adulthood as reflection of earlier childhood events,²⁰ or as predictor of future health problems.¹

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