Lung function in the elderly

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ABSTRACT   Data are presented on the FEV_1 and forced vital capacity (FVC) of elderly people living at home. These were derived from a survey of 418 persons over the age of 70 years and thus provide standards for the assessment of elderly persons. There was a decline in FEV_1 and FVC cross sectionally with age and a continued adverse effect of smoking. A history of cough and phlegm was strongly related to impairment of lung function.

The information hitherto available on lung function of the elderly is rather sparse. One of the largest surveys by Milne and Williamson,[1] was of 487 people aged 62 years and over, but most were under 70 years and only 17 men and 21 women were 80 or more. Nearly all of the men were smokers, so the effect of smoking was not examined. The overall response rate was only 65%,[2] so it is doubtful how far the data represented the population in general. Other workers have conducted surveys with different numbers of elderly subjects selected in various ways.[3–10] We present the results of a survey of a representative sample of elderly people living at home.

Subjects and methods

A survey was carried out among people aged 70 years and over living in Barry, a non-mining town in South Wales. A one in eight sample was drawn from all those in this age group who were registered with local general practitioners. Residents of old people's homes and long stay geriatric wards were excluded. The subjects were seen at a clinic or, if they were unable to attend, in their own homes. A short questionnaire was administered that included the questions about cough and phlegm from the Medical Research Council Questionnaire on Respiratory Symptoms.[11] Forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were measured with a McDermott spirometer. Five values of each were recorded and the mean of the three highest was taken as the best estimate of the true reading. Height was measured with a portable

stadiometer and weight with a beam balance in the clinic or portable scales at home. Body mass index was calculated for each subject as the weight in kilograms divided by the square of the height in metres. Other details have already been published.[12]

It is necessary to standardise FEV_1 and FVC for age and height when subjects are compared with one another. Standardisation has conventionally been carried out by means of a multiple regression technique, but Cole[13] has proposed an alternative model combining a proportional and a linear relationship, using the formula $FEV_1 = height^k (c + d.age)$, where k is approximately equal to 2, c is a constant, and d is a regression coefficient on age, c and d having different values in smokers and non-smokers. We analysed our data both by the traditional method and by Cole's method. The actual values obtained for each subject were compared with those that were predicted by the two methods, paired comparison *t* tests being used to see whether the differences between actual and predicted values differed significantly from zero.

Results

Of the 153 men and 332 women who were eligible for the survey, 138 men aged 70–88 years and 280 women aged 70–101 years participated, giving response rates of 90% and 84% (86% overall). Two women (aged 88 and 90 years) were unable to perform the lung function tests satisfactorily. Table 1 shows the mean height and body mass indices of the subjects in various age and sex groups.

LUNG FUNCTION, AGE AND HEIGHT
Age and height were found to be strongly associated with FEV_1 and FVC. The correlation coefficients between FEV_1 and age were -0.26 in men and

Table 1 *Height and body mass of the subjects*

Age (y)	n	Height (m) Mean(SD)	Body mass index (kg/m²) Mean(SD)
MEN			
70–74	66	1·69 (0·07)	25·2 (3·7)
75–79	40	1·68 (0·07)	23·7 (4·0)
80+	32	1·64 (0·06)	23·3 (3·1)
All men	138	1·68 (0·07)	24·4 (3·8)
WOMEN			
70–74	123	1·56 (0·06)	25·8 (5·0)
75–79	74	1·54 (0·05)	25·4 (4·6)
80+	81	1·51 (0·06)	25·7 (4·8)
All women	278	1·54 (0·06)	25·7 (4·8)

−0·36 in women; between FEV_1 and height they were 0·23 and 0·40—all highly significant ($p < 0.01$ in men and $p < 0.001$ in women in each case). For FVC the coefficients were somewhat higher ($p < 0.001$ in each case). There was no association between FEV/FVC% and age or height. In general, the relationships observed with FVC were very similar to those for FEV_1; where results relating to FVC are not presented, details may be obtained from the authors.

Regression equations were derived from the data by both methods of standardisation and the resulting predicted values compared with each other and with the actual values obtained. In the men the predicted values produced by the two methods were remarkably close; for men aged 70–90 years (height 1·6–1·8 m) the FEV_1 values predicted by Cole's method never differed from those derived by the traditional method by more than 3%. For women aged 70–90 years (height 1·45–1·65 m) after two outliers aged 96 and 101 (the two oldest women) had been excluded, the predicted values derived by Cole's method were all within 9·5% of those derived by the traditional method. There were no significant differences between the actual and the predicted values with either method. The results presented here are based on Cole's method of standardisation.

Table 2 shows the results obtained in three different age groups. In each case FEV_1 and FVC values

have been standardised to the overall mean height of 1·68 m for men and 1·54 m for women, and the adjusted values are referred to as FEV_1* and FVC*. Thus

$$FEV_1* = \frac{FEV_1}{ht^2} \times 1.68^2 \text{ for men.}$$

Table 2 shows that FEV_1* and FVC* decline with age in both men and women whereas FEV/FVC% remains fairly constant.

SMOKING HABIT
Among the men 14% were classified as non-smokers, 43% as ex-smokers, and 43% as current smokers compared with 72%, 10%, and 18% for the women. Seventeen men who smoked pipes or cigars were included as current smokers. Of the 59 male ex-smokers, 18 had given up smoking in the last five years; of the 29 women ex-smokers, 11 had given it up in the last five years.

Figure 1 shows the regression lines of FEV_1* on age. In men the non-smokers had higher FEV_1* values at all ages than ex-smokers or current smokers. The FEV_1* of ex-smokers was similar to that of the smokers. The effect of age on FEV_1* did not differ between the three groups, and the effect of smoking was significant after adjusting for age ($p < 0.01$). In women the non-smokers had the highest FEV_1* at all ages, but the differences from the ex-smokers and current smokers were less than for men. Again, the effect of age was similar in all groups, and the effect of smoking was significant ($p < 0.05$) after adjustment for age.

COUGH AND PHLEGM
Subjects were classified as having persistent cough and phlegm if they had both symptoms on most days for at least three months each year. Thirty three men (24%) and 34 women (12%) fulfilled these criteria. Among the non-smokers, ex-smokers, and smokers the prevalence of cough and phlegm was 11%, 24%, and 28% in men and 9%, 21%, and 18% in women;

Table 2 *Standardised lung function measurements and age*

Age (y)	n	FEV₁* (1) Mean(SD)	FVC* (1) Mean(SD)	FEV₁/FVC% Mean(SD)
MEN				
70–74	66	2·03 (0·74)	3·30 (0·81)	60·2 (14·1)
75–79	40	1·85 (0·66)	3·24 (0·66)	55·7 (14·6)
80+	32	1·57 (0·65)	2·67 (0·66)	57·0 (14·4)
All men	138	1·86 (0·72)	3·14 (0·78)	58·2 (14·4)
WOMEN				
70–74	123	1·44 (0·37)	2·11 (0·43)	68·1 (9·9)
75–79	74	1·39 (0·40)	2·00 (0·51)	69·5 (9·4)
80+	81	1·18 (0·39)	1·77 (0·46)	66·5 (12·1)
All women	278	1·36 (0·40)	1·98 (0·49)	68·0 (10·5)

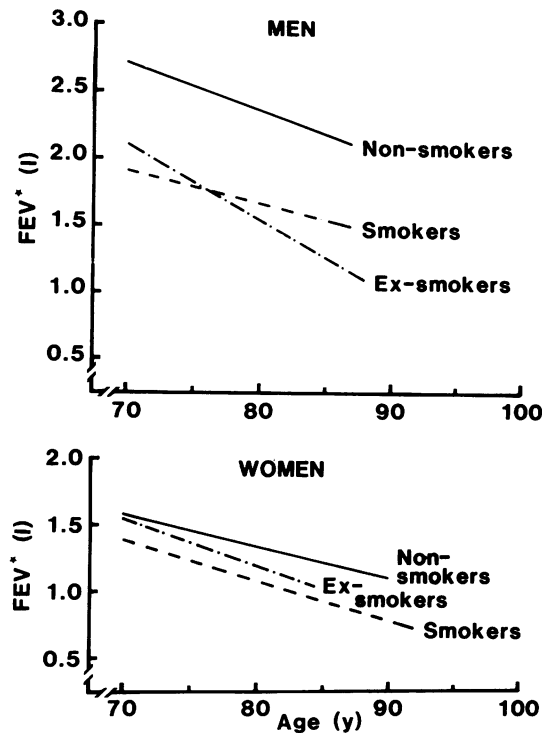*For definitions of FEV_1* and FVC* see text.

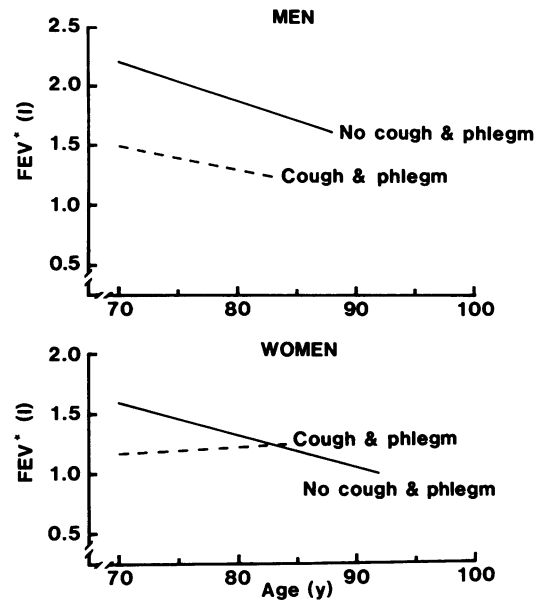Fig 1 *FEV₁ in subjects with different smoking habits, standardised to height 1·68 m (men) and 1·54 m (women).*

Fig 2 *FEV₁ in subjects with and without cough and phlegm, standardised to height 1·68 m (men) and 1·54 m (women).*

a χ^2 test shows the association to be significant in the men (p < 0·05). Owing to the small numbers in some of the subgroups it was not possible to analyse the joint association of smoking and symptoms with lung function.

Table 3 *Constants and coefficients for regression equations*

	n	Constant	Regression coefficient on age	SEM of regression coefficient	Residual SD
Male FEV/ht²					
Non-smoker	19	1·959 ⎫			
Ex-smoker	59	1·697 ⎬	−0·014	0·005	0·232
Smoker	60	1·697 ⎭			
Female FEV/ht²					
Non-smoker	198	1·378 ⎫			
Ex-smoker	29	1·336 ⎬	−0·010	0·002	0·156
Smoker	49	1·286 ⎭			
Male FVC/ht²					
Non-smoker	19	2·680 ⎫			
Ex-smoker	59	2·433 ⎬	−0·018	0·005	0·256
Smoker	60	2·465 ⎭			
Female FVC/ht²					
Non-smoker	198	1·822 ⎫			
Ex-smoker	29	1·845 ⎬	−0·013	0·002	0·188
Smoker	49	1·750 ⎭			
Male FEV/ht²					
Cough and phlegm	33	1·283 ⎫			
No cough or phlegm	105	1·509 ⎭	−0·011	0·005	0·229
Female FEV/ht²					
Cough and phlegm	34	1·229 ⎫			
No cough or phlegm	242	1·342 ⎭	−0·010	0·002	0·155
Male FVC/ht²					
Cough and phlegm	33	2·126 ⎫			
No cough or phlegm	105	2·298 ⎭	−0·015	0·005	0·257
Female FVC/ht²					
Cough and phlegm	34	1·749 ⎫			
No cough or phlegm	242	1·826 ⎭	−0·013	0·002	0·188

Table 4 *Predicted values for FEV₁ and FVC for 70 year old subjects without cough or phlegm, of height 1·6 m (men) and 1·5 m (women), derived from various surveys*

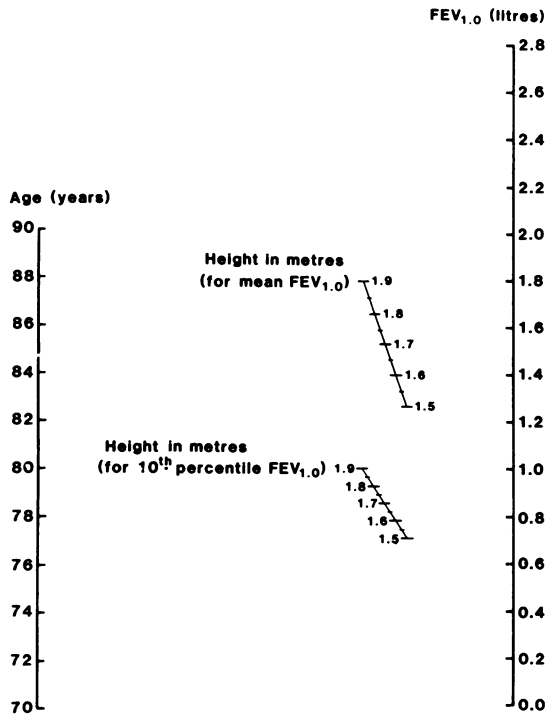| Survey	Men		Women	
	FEV_1 (1)	FVC (1)	FEV_1 (1)	FVC (1)
Needham[3]	—	2·73	—	1·92
Pemberton[4]	—	2·98	—	—
Berglund[5]	2·41	3·84	1·74	2·39
Ferris[6]	2·22	2·86	1·59	1·94
Milne[1]	1·96	2·72	1·46	1·79
Present study	1·89	3·19	1·44	2·06

MEN

Fig 3 *Nomogram for FEV₁ in men. The lower height scale gives the 10th percentile of FEV₁. The nomograms are for all men; more accurate predictions, taking account of smoking habits and symptoms, can be obtained from Cole's formula[14] (see under "Methods") with the constants and regression coefficients in table 3.*

Figure 2 shows the regression lines of FEV_1* against age for subjects with and without cough and phlegm. The regression lines for subjects with symptoms do not extend as far as those for symptom free subjects since the former group did not reach as high an age; the oldest man and woman with cough and phlegm were aged 83 and 84 years respectively. Women with cough and phlegm did not show the decline in FEV_1* with age seen with the symptom
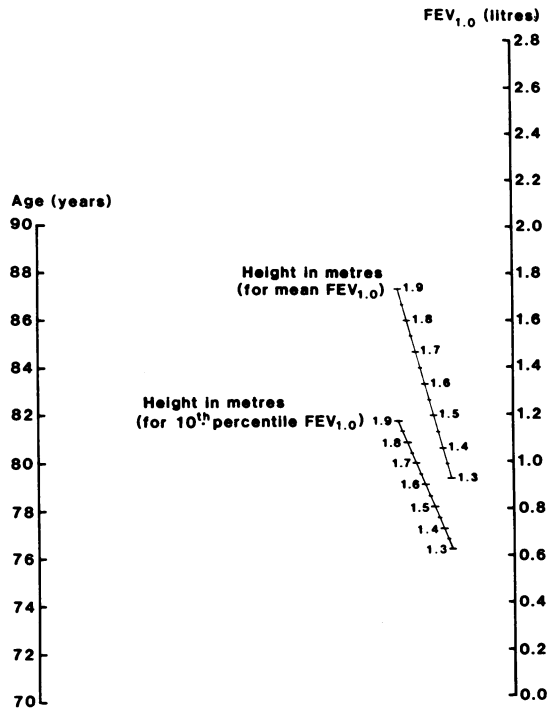
WOMEN

Fig 4 *Nomogram for FEV₁ in women (see legend to fig 3).*

free women, although the difference in slope was not significant (p > 0·05). The effect of cough and phlegm on FEV_1* was significant (p < 0·001) after adjustment for age in both men and women.

The effects of wheezing and breathlessness on lung function were similarly examined. As expected, both these symptoms were associated with lower FEV_1* and FVC* values, although in general the effects were not as great as those of cough and phlegm. Details of these relationships may be obtained from the authors.

PREDICTION OF LUNG FUNCTION
Population data are used to predict the lung function of a subject of a given age and height. Table 3 shows the constants and regression coefficients for smoking cough, and phlegm (corresponding respectively to c and d in Cole's formula) in men and women for FEV_1 and FVC. To obtain a predicted FEV_1 or FVC for an individual the age should be multiplied by the appropriate regression coefficient, the constant added, and the sum multiplied by the square of the height in metres. The two women older than 95 years are omitted from the data in tables 3 and 4 and figures 1, 2, 4, and 6, since their values are "out-
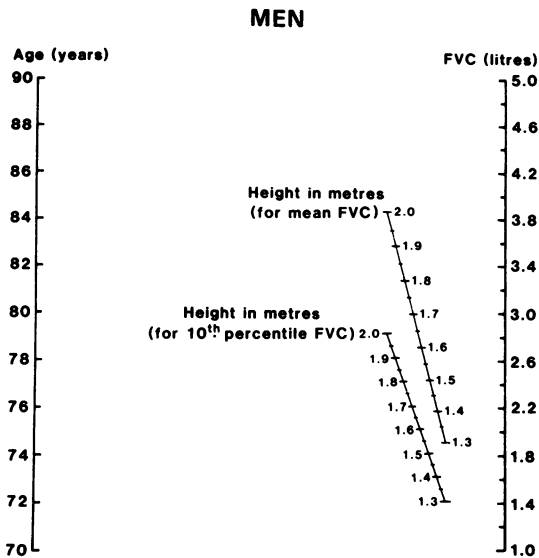
MEN

Age (years)

FVC (litres)

Height in metres
(for mean FVC)

Height in metres
(for 10ᵗʰ percentile FVC)

Fig 5 *Nomogram for forced vital capacity (FVC) in men (see legend to fig 3).*

liers" and exert a disproportionate and distorting effect on the overall data. Figures 3–6 present the data from all men and women in the form of nomograms.
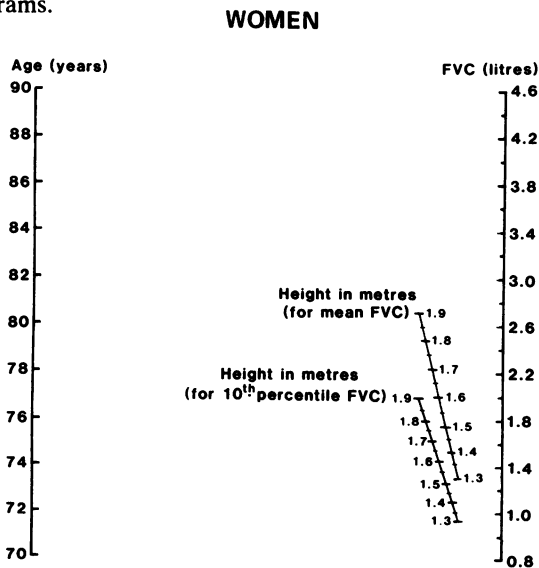
WOMEN

Age (years)

FVC (litres)

Height in metres
(for mean FVC)

Height in metres
(for 10ᵗʰ percentile FVC)

Fig 6 *Nomogram for forced vital capacity (FVC) in women (see legend to fig 3).*

Discussion

The data presented here provide a basis for predicting FEV_1 and FVC indices for people in their 70s

and 80s. These predictions are likely to be more accurate than those derived from smaller numbers of elderly people or extrapolated from results obtained in younger persons. Residents of old people's homes and inpatients in long stay hospital wards were not included in the survey. These people are likely to have poorer lung function, so it must be borne in mind that the data presented here relate to old people living at home. The response rate of 86% indicates that the subjects seen were reasonably representative of the sample population, but again those who refused are likely to have had poorer rather than better lung function. The town concerned does not have an industrial history of coal mining and contains a balanced distribution of social classes. These data may reasonably be assumed to represent the United Kingdom in general, although area differences may exist and are being investigated in separate studies.

Age is associated with a decline in FEV_1 and FVC for almost every sub group. It must be recognised, however, that special issues arise when associations with age are studied cross sectionally in an elderly population. There is much evidence to show that poor lung function is highly predictive of mortality, so that persons with a low FEV_1 and FVC will tend not to survive to the older ages. A survival effect therefore plays an important part in cross sectional data, and the figures must not be read as representative of longitudinal changes within individuals. These would presumably show on average an even steeper decline.

These data have been analysed with Cole's formula[13] rather than traditional methods of standardising FEV_1 and FVC for age and height. Cole fitted his model by maximum relative likelihood and compared it with the linear regression model using Edwards' method of support. He showed that for his initial set of data the proportional model was appreciably better supported than the linear model, and that the parameter k was very close to 2. He confirmed this by reanalysing the results of nine studies of ventilatory function from all over the world, including over 11,000 men and women. Only one of these studies included subjects over the age of 75 years, however, and in this survey they formed a very small proportion of the total number (95 out of 6365 subjects tested).[14] We found little difference between the values predicted by the two methods for elderly persons using our data; in view of Cole's evidence we have used his method in presenting these results.

The regression equations can be used to predict FEV_1 and FVC in various groups of elderly people. Such equations have been produced by other workers, but the surveys concerned have had wider age

ranges, with relatively few subjects over the age of 70 years. These formulae may therefore not be reliable for older people. The subjects in these surveys have been selected and classified in different ways, so comparisons between our results and theirs must be made with caution. Furthermore, the regression equations have in general conformed to the multiple regression model whereas this survey uses Cole's formula, which combines a proportional and a linear relationship.

Table 4 shows the values predicted by various workers for 70 year old men and women of heights 1·6 m and 1·5 m, with no cough or phlegm. The male values show considerable variation between the different studies. Our predictions for FEV_1 are similar to those of Milne and Williamson, while our FVC values are somewhat higher. For $FEV_1/FVC\%$ in subjects aged 70 years, with no cough or phlegm, our predictions of 66·2% for men and 68·1% for women are much closer to those of Berglund *et al* (65·7% and 73·8%) than to those of Milne and Williamson (70·9% and 81·0%).

Smoking clearly continues to affect lung function into advanced old age. The effect is much greater in the men than in the women, perhaps because of a greater cigarette consumption. The ex-smokers are on the whole similar to the current smokers as regards both lung fuction and symptoms, probably because lung damage is a factor inducing people to stop smoking.[15][16]

The symptoms of cough and phlegm were associated with smoking and a substantial reduction in lung function. The relationship between symptoms, lung function, and age is complex, since in addition to a survival effect (discriminating against those with symptoms and poor lung function) there will be some recruitment with age into the symptomatic group having symptoms as more people develop cough and phlegm. This may explain the apparent lack of decline in FEV_1 with age in the women with cough and phlegm; a longitudinal study of individuals would almost certainly show a different pattern.

References

1 Milne JS, Williamson J. Respiratory function tests in older people. *Clin Sci* 1972;**42**:371–81.
2 Milne JS, Maule MM, Williamson J. Method of sampling in a study of older people with a comparison of respondents and non-respondents. *Br J Prev Soc Med* 1971;**25**:37–41.
3 Needham CD, Rogan MC, McDonald I. Normal standards for lung volumes, intrapulmonary gas mixing and maximum breathing capacity. *Thorax* 1954;**9**:313–25.
4 Pemberton J, Flanagan EG. Vital capacity and timed vital capacity in normal men over forty. *J Appl Physiol* 1956;**9**:291–6.
5 Berglund E, Birath G, Bjure J, *et al*. Spirometric studies in normal subjects. I. Forced expirograms in subjects between 7 and 70 years of age. *Acta Med Scand* 1963;**173**:185–92.
6 Ferris BG, Anderson DO, Zickermantel R. Prediction values for screening tests of pulmonary function. *Am Rev Respir Dis* 1965;**91**:252–61.
7 Caird FI, Akhtar AJ. Chronic respiratory disease in the elderly: a population study. *Thorax* 1972;**27**:764–8.
8 Medical Research Council. *Questionnaire on Respiratory Symptoms*. London: MRC, 1976.
9 Buist AS, Van Fleet DL, Ross BB. A comparison of conventional spirometric tests and the test of closing volume in an emphysema screening center. *Am Rev Respir Dis* 1973;**107**:735–43.
10 Schmidt CD, Dickman ML, Gardener RM, Brough FK. Spirometric standards for healthy elderly men and women. *Am Rev Respir Dis* 1973;**108**:933–9.
11 Burrows B, Cline MG, Knudson RJ, Taussig LM, Lebowitz MD. A descriptive analysis of the growth and decline of the FVC and FEV_1. *Chest* 1983;**83**:717–24.
12 Burr ML, Charles TJ, Roy K, Seaton A. Asthma in the elderly: an epidemiological survey. *Br Med J* 1979;i:1041–4.
13 Cole TJ. Linear and proportional regression models in the prediction of ventilatory function [with discussion]. *J R Stat Soc Ser A* 1975;**138**:297–338.
14 Higgins MC, Keller JB. Seven measures of ventilatory lung function. *Am Rev Respir Dis* 1973;**108**:258–72.
15 Doll R, Hill AB. Mortality in relation to smoking: ten years' observations of British doctors. *Br Med J* 1964;i:1399–410.
16 Fletcher C, Peto R. The natural history of chronic airflow obstruction. *Br Med J* 1977;i:1645–8.