Pulmonary function of London firemen

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ABSTRACT In a longitudinal study of a sample of firemen in London 1006 firemen were interviewed and examined in 1976 and 895 were seen a second time 12 months later. On each occasion a Medical Research Council respiratory questionnaire was administered and forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) were measured. The average levels of FEV₁, FVC, and FEV₁/FVC in both years compared favourably with conventional predicted values. Separate multiple regression analysis for the two years indicated that the FEV₁ and FVC fell more rapidly in those aged over 40, and that cigarette smoking had a strong harmful effect on these measures of function. Only among men with over 20 years' service was there possibly any evidence (not statistically significant) of an effect from duration of employment. The comparatively large fall in FEV₁ and FVC from 1976 to 1977 was due mainly to instrumental variation. The prevalence of respiratory symptoms was higher in smokers than non-smokers and increased with the number of cigarettes smoked.

This study is the first to be reported on respiratory function of firemen in the United Kingdom. Before its conception in 1975 work had been reported from the United States¹⁻³ which suggested that respiratory function in firemen declined at a rate significantly greater than expected.

Methods

SAMPLE

Twenty five stations were selected at random from all stations in the London Fire Brigade after stratification by geographical area, numbers of fires attended, and size of station. The selected stations were distributed throughout the 11 divisions of the brigade. The sample consisted of all 1207 men active (in May 1976) in the selected stations, about 20% of the total strength of the brigade.

DATES OF THE STUDY

Each participant was seen once in 1976 and again in 1977, with so far as practicable an interval of 12 months for each fireman. The study was carried out from May to October each year.

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RESPIRATORY FUNCTION TESTS

Forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) were measured in both years using a Vitalograph dry spirometer with digital readout that was calibrated daily. The mechanism of the instrument was serviced at completion of the 1976 fieldwork. In two stations flow volume measurements were also made in each year using an integrating pneumotachograph.

As circadian rhythms have been shown to affect pulmonary function in work people,⁴ tests were performed so far as possible at the same hour of day in each year.

FEV₁ and FVC were measured with the fireman standing and each man performed a least five forced expiratory manoeuvres and the mean of the last three values was used in the analysis. All values were corrected to BTPS. Height in stockings feet was measured only in 1976 and weight was determined in both years.

QUESTIONNAIRE

The 1966 MRC respiratory questionnaire with additional questions about exposure to smoke and part time employment was administered each year.

OCCUPATIONAL EXPOSURE

Measures of occupational exposure used included duration of service in the brigade, whether the firemen had ever been "punished" by smoke, and in

particular whether he had ever been absent for a watch, or longer, after such exposure. The term "punished" is commonly used in the Fire Service for describing severe exposure to smoke.

CIGARETTE SMOKING

Cumulative exposure to cigarettes in pack years was estimated from the reported smoking histories.

STATISTICAL ANALYSIS

The major emphasis is on a cross sectional analysis of the 1976 results. The 1977 results and the differences between the results for the two years were also examined for consistency with trends shown by the 1976 analysis. It is recognised that the 1977 study, being carried out on the same study subjects, cannot give independent confirmation of hypotheses arising from the 1976 study.

Multiple regression⁵ was used to analyse the dependence of FEV_1 , FVC, and FEV_1/FVC on age, height, weight, duration of service, occupational exposure, and cigarette smoking. To allow non-uniform rates of decline with age, piece wise linear regressions⁶ (splines) with joins at ages 20, 25, . . . , and 50 were investigated. In all analyses age refers to age in 1976.

Results

RESPONSE

From the selected sample of 1207 men, 1006 (83.3%) were available and seen in 1976. Of the remaining 201, 121 were on leave or temporary transfer, 43 were absent through sickness, and 37 refused to participate. Of the 1006 men, 895 (89.0%) were seen again in 1977, but five had imperfect records of pulmonary function and were excluded from the analysis. Of the 111 men seen in

1976 but not in 1977, 33 had left the brigade, 39 were on leave or transfer, 33 were absent sick, and three refused.

INTERVAL BETWEEN TESTS

Of the 890 men seen twice, 827 were seen in the same or adjacent month in 1977 as in 1976. The mean interval between tests was 12.4 months.

TIME OF DAY

In both years most men were seen between 10 am and 1 pm. The mean difference in time of test was 8.4 minutes.

FUNCTION RESULTS

Table 1 shows the unstandardised 1976 and 1977 results for FEV_1 , FVC, and FEV_1/FVC . For comparison, the values predicted by the "normal" equations of Kory^{7,8} for men of the same average height (1.78 m) are shown. It is apparent that the firemen on average had excellent lung function. Their results appear comparable with those obtained for North Sea divers by Crosbie.⁹

MULTIPLE REGRESSION ANALYSIS

Piece wise linear regressions on age, with a first order height term, confirmed the impression of an increased rate of decline in function after age 40 but indicated that any further differentiation among age groups was unnecessary for the purpose of estimating rates of decline with age.

Table 2 shows the results of the multiple regression analyses with FEV_1 , FVC, and FEV_1/FVC as response variables, and age (separate slopes at age 40), height, and pack years of cigarettes as predictor variables. The analysis confirmed that all three measures of function decline with age. The change in slopes at age 40 for FEV_1 and FVC was very

Table 1 Lung function measures by age

	Age group	No	Mean (standard deviation) predicted value		
			FEV_1 (l)	FVC (l)	FEV_1/FVC (%)
1976	15-19	10	5.27 (0.48) 4.50	6.35 (0.91) 5.54	83.7 (6.2) 85.5
	20-24	216	5.12 (0.64) 4.35	6.18 (0.71) 5.43	83.1 (6.3) 83.6
	25-29	309	4.97 (0.65) 4.21	6.13 (0.76) 5.32	81.3 (6.3) 81.7
	30-34	238	4.79 (0.62) 4.06	6.01 (0.73) 5.21	79.9 (6.4) 79.9
	35-39	99	4.74 (0.58) 3.92	5.98 (0.73) 5.10	79.5 (6.3) 78.0
	40-44	66	4.43 (0.73) 3.77	5.73 (0.84) 4.99	77.3 (6.0) 76.1
	45-49	44	4.07 (0.65) 3.63	5.37 (0.64) 4.88	75.7 (7.1) 74.3
	≥50	24	3.71 (0.54) 3.48	5.10 (0.73) 4.77	73.1 (7.9) 72.4
1977	15-19	8	5.19 (0.39) 4.47	6.31 (0.87) 5.52	83.1 (7.6) 85.1
	20-24	196	5.03 (0.61) 4.32	6.09 (0.70) 5.51	82.6 (5.9) 83.2
	25-29	267	4.89 (0.62) 4.18	6.04 (0.75) 5.30	81.2 (6.1) 81.3
	30-34	208	4.66 (0.62) 4.03	5.88 (0.76) 5.19	79.6 (6.6) 79.5
	35-39	93	4.63 (0.54) 3.89	5.85 (0.69) 5.08	79.4 (6.6) 77.6
	40-44	59	4.30 (0.67) 3.74	5.59 (0.79) 4.97	77.0 (6.2) 77.7
	45-49	39	4.09 (0.55) 3.60	5.35 (0.68) 4.86	76.5 (5.6) 73.9
	≥50	20	3.68 (0.54) 3.45	5.11 (0.77) 4.75	72.3 (7.6) 72.0

pronounced in the 1976 results but less evident in the 1977 results. The ratio FEV_1/FVC decreased slightly with increasing height. Smoking a pack of cigarettes a day increased the rate of decline of FEV_1 due to age by about one third.

After correcting for age and height, the heavier men had slightly smaller FEV_1 and FVC values. Duration of service was negatively associated with the function measures, but the rate of decline was small compared with that due to age or cigarette smoking. Absence from work after acute exposure to smoke was associated with only a small loss of function. All coefficients representing effects of occupational exposure were less than twice their standard errors.

Regression analyses of the 1976 function results for the non-smokers only also failed to show any occupational effect. The effect of habitual cigarette smoking on lung function, however, was clearly demonstrated and shown to be related to total consumption.

CHANGES IN LUNG FUNCTION BETWEEN 1976 AND 1977

Among the 890 men tested twice there was a mean decline in FEV_1 of 0.09 l, in FVC of 0.11 l, and in FEV_1/FVC of 0.05 (%). These changes are too large to be consistent with the rates of decline estimated from the cross sectional analysis of the 1976 results. The change in lung function was not related to duration of service, or to absence after exposure to smoke, but there was a statistically significant greater decline among current smokers.

SYMPTOMS AND FLOW VOLUME CURVE

The analysis of the symptom questionnaire and flow volume curves¹⁰ both confirmed the deleterious effects of cigarette smoking and the association with wheeze. No evidence was found regarding any possible occupational risk to firemen, however. The questionnaire data do permit an interpretation of the flow volume measurements such that flow at 25% of vital capacity ($\dot{V}_{25}$) is largely cigarette smoking specific, whereas the flow at 50% ($\dot{V}_{50}$) is more specific for wheeze.

Discussion

EXPOSURE TO SMOKE

Two measures of exposure were used—namely, the duration of service and whether the fireman had ever suffered acute effects from smoke exposure (both self reported). No association was demonstrable between occupational smoke exposure, symptoms, and pulmonary function. Nevertheless, the observation that smoking increased the prevalence of all respiratory symptoms except nasal catarrh must be emphasised and is of overwhelming importance.

PULMONARY FUNCTION

When compared with the values of mean FEV_1 , FVC, and FEV_1/FVC predicted for a "normal" population of similar age and height, the firemen in this study had excellent pulmonary function. This applies to all age groups, although the superiority was more pronounced among younger men. This

Table 2 Multiple regression of lung function on age, height, and cigarette consumption with coefficients and standard errors in parentheses

	No	Constant	Age (<40)	Age (≥40)	Height (m)	Cigarettes*
FEV_1 (l) 1976 (all men)	1006	-4.08	-0.027 (0.003)	-0.051 (0.009)	5.55 (0.31)	-0.0089 (0.0021)
FEV_1 (l) 1976 (seen also in 1977)	890	-3.98	-0.027 (0.004)	-0.050 (0.009)	5.46 (0.32)	-0.0094 (0.0022)
FEV_1 (l) 1977	890	-3.65	-0.028 (0.003)	-0.043 (0.009)	5.24 (0.31)	-0.0095 (0.0021)
FVC (l) 1976 (all men)	1006	-7.26	-0.015 (0.004)	-0.044 (0.009)	7.77 (0.33)	-0.0063 (0.0022)
FVC (l) 1976 (seen also in 1977)	890	-7.01	-0.016 (0.004)	-0.042 (0.010)	7.64 (0.35)	-0.0063 (0.0024)
FVC (l) 1977	890	-7.04	-0.018 (0.004)	-0.034 (0.010)	7.62 (0.35)	-0.0064 (0.0024)
FEV_1/FVC (%) 1976 (all men)	1006	108.7	-0.24 (0.04)	-0.33 (0.10)	-11.4 (3.50)	-0.073 (0.024)
FEV_1/FVC (%) 1976 (seen also in 1977)	890	105.9	-0.23 (0.04)	-0.34 (0.11)	-10.0 (3.70)	-0.080 (0.026)
FEV_1/FVC (%) 1977	890	112.3	-0.22 (0.04)	-0.33 (0.11)	-13.8 (3.70)	-0.081 (0.025)

*Units (pack of 20 a day) × years.

result is not surprising as firemen undergo rigorous selection procedures before joining the brigade and need to remain fit to carry out their tasks. That these firemen were "fit" by normal lung function standards does not necessarily prove that they have not been affected by exposure to smoke. None the less, within the limits of sensitivity of these well recognised and validated tests no adverse effects were apparent. This supports a mortality study by Musk *et al*, which found no excess of respiratory deaths and, apart from an SMR of 135 for accidents for active fire fighters, no association between the occupation of firefighting and cause specific mortality.¹¹

EFFECT OF AGE AND DURATION OF SERVICE

Analysis of the 1976 function results suggested that the regression with age increased somewhat around age 40. After standardising for age and height no clear relation with duration of service emerged, nor with past acute effects from exposure to smoke; the men with over 20 years' service appeared to have somewhat lower lung function values but not statistically significant.

COMPARISON WITH BOSTON STUDY

This investigation has provided evidence that, in terms of lung function, the study population behaved differently from expected. Apart from the higher than expected values of FEV₁ and FVC, the longitudinal study showed an apparent annual loss of 92 ml for FEV₁ (28 ml expected) and 107 ml for FVC (22 ml expected). On the other hand, the same data analysed as two cross sectional studies showed much lower average annual decrements.

The Boston study found similar conflicting results. In the first report³ the longitudinal study showed a difference in one year of 68 ml for FEV₁ and 77 ml for FVC. The authors concluded that these differences were due to occupational exposures. This loss of pulmonary function was not observed, however; when the tests were repeated after three years when the mean annual loss was 30 ml for FEV₁ and 40 ml for FVC.¹²

The fact that the large differences disappeared when the time between tests increased from one to three years in Boston, and the fact that in the London study the findings of the longitudinal analysis were not supported by cross sectional analyses, suggests that in both studies a small but systematic change in survey conditions or methods may have influenced the results. A systematic difference of 2% between the two years would produce the relatively large differences in FEV₁ and FVC. The same systematic difference averaged over several years would have far less effect. Support for such a theory is provided in the London study by the lack of any correlation between indices of occupational expos-

ure and apparent loss of FEV₁ or FVC.

Several possible sources of variation were investigated. By contrast with the cross sectional analysis, a longitudinal analysis did show statistically significant variations in the decline between the 25 sampled stations. Differences in the time at which the test was taken are unlikely to have been important contributory factors but the effect of the 1976 heat wave is an unknown quantity.

In our view, likely possible sources of the change are instrumental variation and the use of different operators in the two years. Clearly, however, for the purpose of accurately tracing the behaviour of function in individuals, a much longer period of follow up would be desirable. Berry suggests a minimum of five years.¹³ A one year follow up is too short to disentangle small changes in survey technique from real changes in function.

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