15 YEAR LONGITUDINAL STUDIES OF FEV_1 LOSS AND MUCUS HYPERSECRETION DEVELOPMENT IN COAL WORKERS IN NEW SOUTH WALES, AUSTRALIA

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Recent longitudinal studies from the United Kingdom[9] and the United States[1] have shown that coal mine workers suffer a decline in FEV_1 which is a function of age, height, smoking habit and respirable dust exposure. Although each of these studies has been criticized for bias due to the restriction of the study to current workers who had been examined and re-examined after an 11 year interval[10] it has been shown that those workers who leave the coal mining industry do not differ greatly in their response to dust exposure, thus suggesting that any such bias is small.[11]

Previous cross-sectional studies in New South Wales have shown clear positive associations between chronic mucus hypersecretion and age, smoking, relative dust exposure and alcohol consumption and similar, but less clear, associations between airways obstruction (loss of FEV_1) and the above factors.[8] Comparison of multiple regression analyses of the entire workforce examined in 1971–74 and 1977–80 showed that the negative regression relationship of FEV_1 with relative dust exposure (years worked at face) was statistically significant at the 5% level only in the earlier study, which would have included more men who had worked in a period of poorer dust control (i.e., before about 1955).[7] To confirm these findings and to enable more direct inferences as to the relative aetiological significance of dust exposure, smoking and alcohol on chronic mucus hypersecretion and airways obstruction, two complementary longitudinal studies based on the entire NSW workforce were carried out. In the first study, methodology was deliberately chosen to be comparable with the U.K. and U.S. studies mentioned above. In the second study a somewhat different methodology was used to provide further information about the actual time course of changes in both airway obstruction and chronic mucus hypersecretion, as a function of age, smoking, relative dust exposure and alcohol consumption.

STUDY 1

Methods

In New South Wales, all mineworkers are examined in regional medical bureaus, by occupational physicians, every 2–3 years. At each examination, a full smoking and alcohol consumption history are obtained. Standing height without shoes and FEV_1 (better of two satisfactory efforts, Vitalograph Spirometer ATPS 20°C) are measured. Data are recorded in a standardized fashion and maintained in a computer-based records system.[5]

All workers who had been examined in the period 30 June 1970–30 June 1973 and in the period 30 June 1983–30 June 1986 *and* at least once in the intervening period were included in the study. From the computer-based records system, the following data were extracted:

1. Age at latest examination (years).
2. Height at latest examination (cm).
3. Tobacco smoked per week (gm/wk)
   - 3.1. at initial examination (previous smoking amount)
   - 3.2. mean of all examinations, including initial examination (concurrent smoking amount).
4. Alcohol consumed per week (gm/wk) (mean of all examinations).
5. Dust exposure index at initial examination (6 × years worked underground at face + 1 × years worked underground not at face prior to initial examination). The ratio 6:1 corresponds to the ratio of mean full shift gravimetric exposures in the two sites.
6. Dust exposure index between examinations (6 × years worked underground at face + 1 × years worked underground not at face between examinations). (Concurrent dust exposure).
7. Standardized change in FEV_1, (ΔFEV_1, L)

$$\frac{(FEV_1\ (1970\text{–}73) - FEV_1\ (1983\text{–}86)) \times 15}{\text{(actual years between)}}$$

The sample comprised 2,807 men. This represented 24.5% of the men who were examined between 1970–73 and had complete data for all variables.

Results

Means and standard deviations of all variables are shown in Table I. The multiple regression of ΔFEV_1 on variables 1–6 was calculated. The results are shown in Table I.

It can be seen from Table I that ΔFEV_1 has significant ($P<0.05$) positive regression coefficients on age, previous dust exposure, previous smoking amount and alcohol consumption but not on height, concurrent smoking amount or concurrent dust exposure.

Table II shows some significant correlations among the independent variables, but with the exception of age/previous exposure ($r = 0.38$), they are low (<0.19). A high age/exposure correlation is a consistent feature of all epidemio-

Table I
Means and Regression Coefficients

			Mean (SD)
y variable			
ΔFEV_1 = ($\frac{FEV_1\ 1970\text{-}73 - FEV_1\ 1983\text{-}86}{\text{actual years between}}$) X 15 (litres)			0.81(0.81)
x variables	**b**	**P**	
Age at last examination (year)	0.75×10^{-2}	<0.001	45.5(8.9)
Height at last examination (centimetres)	0.72×10^{-3}	NS	173(19)
Dust exposure index (concurrent)	-0.24×10^{-4}	NS	43.9(39.5)
Dust Exposure index (previous)	0.14×10^{-2}	<0.001	21.3(35.8)
Tobacco gm/wk (concurrent)	0.83×10^{-4}	NS	49.4(106)
*Tobacco gm/wk (previous)	0.33×10^{-3}	<0.01	57.2(130)
Alcohol gm/wk	0.18×10^{-3}	<0.05	171(168)
Constant			0.24
R = 0.14 n = 2807			

* Included in a separate analysis. Other regression coefficients remained stable to 2 decimal places.

logical studies in a relatively stable workforce. The two variables, however, were retained in the multiple regression as separate variables of independent patho physiological interest. Mean loss of FEV_1 in 15 years was 0.81L (SD 0.81L). Mean FEV_1 in 1970–73 was 3.77L; mean FEV_1 in 1983–86 was 2.96L. It is interesting to note that the cross-sectional regression coefficient for age was −0.038 L/yr giving an estimated loss in 15 years of 0.6L.[7]

Discussion

The mean loss of FEV_1 of 0.81L in 15 years is in good agreement with the U.K. and the U.S. studies[9,1] which found mean FEV_1 losses in 11 years of 0.5L, 0.48L respectively. Mean FEV_1 loss in a "normal" population is about 0.3L in 11 years.[2]

The cohort in the present study was slightly younger than in the U.K. and U.S. studies (mean age at final examination 45 compared to 50 (U.K.) and 49 (U.S.)).

Loss of FEV_1, was related to previous dust exposure and previous smoking amount. Mean smoking amount reduced significantly in the 15 year period (57.2 gm/wk in 1970–73; 49.4 gm/wk (average of all examinations including 1970–73). The proportion of smokers in 1970–73 was 55% while in 1983–87 it was 43%.

Table II
Correlation Coefficients

	Age	Height	Dust (Concurrent)	Dust (Previous)	Smoking§	Alcohol
Age	1.00					
Height	-0.07	1.00				
Dust (concurrent)	0.10*	-0.02	1.00			
Dust (previous)	0.38*	-0.03	0.19*	1.00		
Smoking§	-0.02 0.02	0.02 0.00	0.00 0.00	0.02 0.03	1.00 1.00	
Alcohol	0.11*	0.03	0.03	0.10*	0.12*	1.00

* P<0.0001

§ upper figure is smoking (concurrent)
lower figure is smoking (previous)

The lack of relationship of loss of FEV_1 to concurrent smoking is thus not as surprising as it would seem at first glance. Men already affected by obstructive lung disease continued to lose FEV_1, even though their smoking habit was reduced.

The lack of relationship of loss of FEV_1 to concurrent dust exposure is also not surprising. Most of the obstructive lung disease due to dust would have developed in the men exposed to the higher dust concentrations obtained prior to 1955. These men would have continued to deteriorate whilst those exposed to concurrent dust concentration would not be so severely affected.

This finding is consistent with previous cross sectional studies on the New South Wales workforce[7] and with the U.K. longitudinal study.[9] The finding of a lack of association of loss of FEV_1 with height is difficult to explain. Both the U.K. and U.S. studies showed a strong positive relationship between FEV_1loss and height, which would be expected if smoking and dust exposure caused a proportional detriment in lung function in men of different heights. As Morgan notes, there is nothing to suggest that height itself renders an individual more or less likely to emphysema or chronic bronchitis.[10]

A possible explanation of the finding in the present study is the inclusion in the study group of taller men who work in open cut mines. Underground and face workers tend to be self selected for smaller stature because of low roof conditions in some mines. These are the workers exposed to the highest dust levels. This effect would oppose the normal proportional loss effect and thus lead to a non-significant regression coefficient. Neither the U.K. nor U.S. study included open-cut workers.

It is possible to make rough estimates of the relative effects of previous smoking and previous dust exposure on FEV_1 loss. The respective regression coefficients are 0.33×10^{-3} L. $gm.^{-1}$ wk, and 0.14×10^{-2} L. unit of dust exposure $index^{-1}$ Thus the effect of having smoked 140 gm/wk (20

cigarettes/day) prior to 1970 is a loss of 46.2 mL in 15 years whereas the effect of having worked continuously at the face for 10 years prior to 1970 (assuming the average man aged 30 in 1970 would have started work at 20) would be a loss of 84 mL. This analysis is a little misleading as it does not take into account either the variance of the dependent and independent variables or the correlation of previous dust exposure with age. An alternative examination of the relative effects can be made by comparing the standardized regression coefficients for previous smoking (0.056) and previous dust exposure (0.062), suggesting a roughly equal effect.

STUDY 2

Methods

The study cohort comprised all workers who had been examined and had complete data at each of the successive 5 year intervals from 1970. The examination nearest in time to 30 June 1970, 1975, 1980, 1985 was taken as the reference examination for each interval. This study cohort comprised 847 men. At each examination, FEV_1, smoking and alcohol data were obtained as above. In addition, the presence or absence of chronic mucus hypersecretion was ascertained by a modified MRC respiratory symptom questionnaire.[8] The cohort was subclassified into four age cohorts (aged 16–25(1) (130 men), 26–35(2) (214 men), 36–45(3) (269 men), 46–55(4) (234 men) in 1970. In each 5 year interval these cohorts were further subclassified by relative dust exposure, smoking amount and alcohol consumption as follows:

Relative Dust Exposure

High: Majority of 5 year period working underground at face.
Medium: Majority of 5 year period working underground not at face.
Low: Majority of 5 year period working in surface.

Smoking Amount

Non-Smoker
Ex-Smoker
1–84 gm/wk tobacco (Low)
>84 gm/wk tobacco (High)

Alcohol Consumption

High: >300 gm/wk (High)
Low: <300 gm/wk (Low)

The dependent variables were chronic mucus hypersecretion (% affected) and mean FEV_1/ht^2.[3]

Results

Figures 1–6 show the development of chronic mucus hypersecretion and airways obstruction with time for each age subcohort, as a function of relative dust exposure, smoking amount and alcohol consumption.

There is a clear relationship between chronic mucus hypersecretion and both dust exposure and smoking amount in all age subcohorts. In cohorts 1, 3, 4 the same relationship is apparent for alcohol consumption. There is a progressive increase of chronic mucus hypersecretion with time.

Airway obstruction also shows a progressive increase with time in all subcohorts. There is a strong relationship with smoking amount and a weaker relationship with dust exposure and alcohol consumption. It should be noted that the "sub-subcohorts" at any time may include different individuals, as smoking habit, drinking habit and work site may change between examinations. For this reason we were uncertain as to how best to statistically analyse the data. As statistical analysis of longitudinal data of this type is still in a developmental phase we decided to merely present for visual inspection the time course of means and proportions by sub-subcohort.

However, the results of studies 1 and 2, taken together, clearly show that concurrent dust exposure, concurrent smoking and alcohol consumption are associated with increased mucus hypersecretion and that dust exposure and smoking before 1970 are associated with the development of airways obstruction.

These findings and also consistent with pathological studies demonstrating dust induced bronchitis[4] and emphysema[6] in coal workers. Alcohol consumption has been shown to reduce mucociliary clearance[12] and the adverse effects of smoking are universally accepted. There thus exists a clear patho physiological basis for the findings.

Conclusion

Longitudinal studies of the entire New South Wales working coal industry workforce show a clear association between past dust exposure, smoking and alcohol consumption and the development of chronic mucus hypersecretion and airways obstruction.

We have not followed up exworkers but evidence from other studies suggests that this does not cause significant bias.

Any such bias is likely to be in the direction of a "healthy worker effect" whereby the least affected remain at work. Hence these studies are likely to have underestimated the effects of dust exposure on lung function in coal workers.

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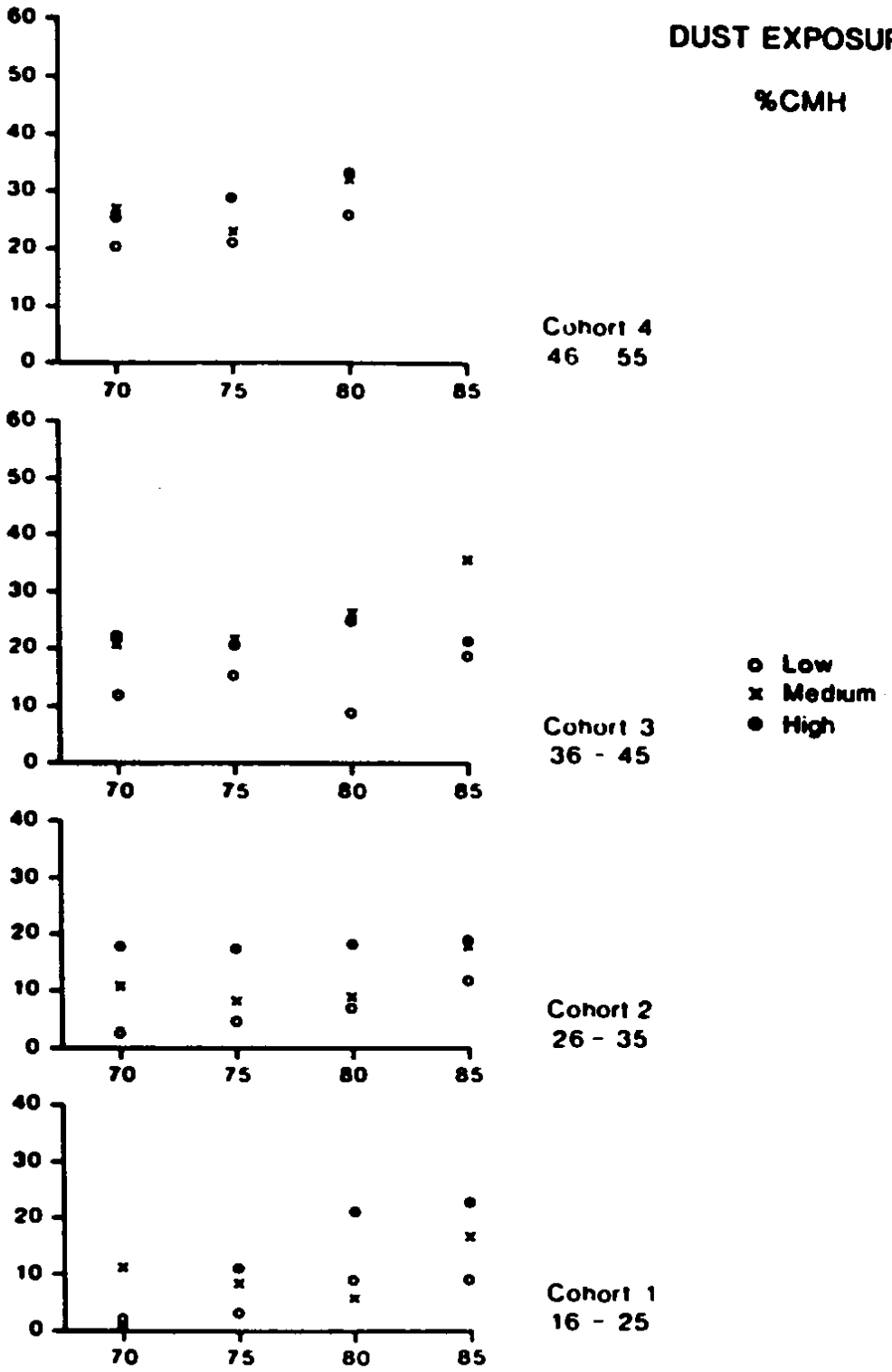

Figure 1. Development of chronic mucus hypersecretion by age and time related to relative dust exposure.

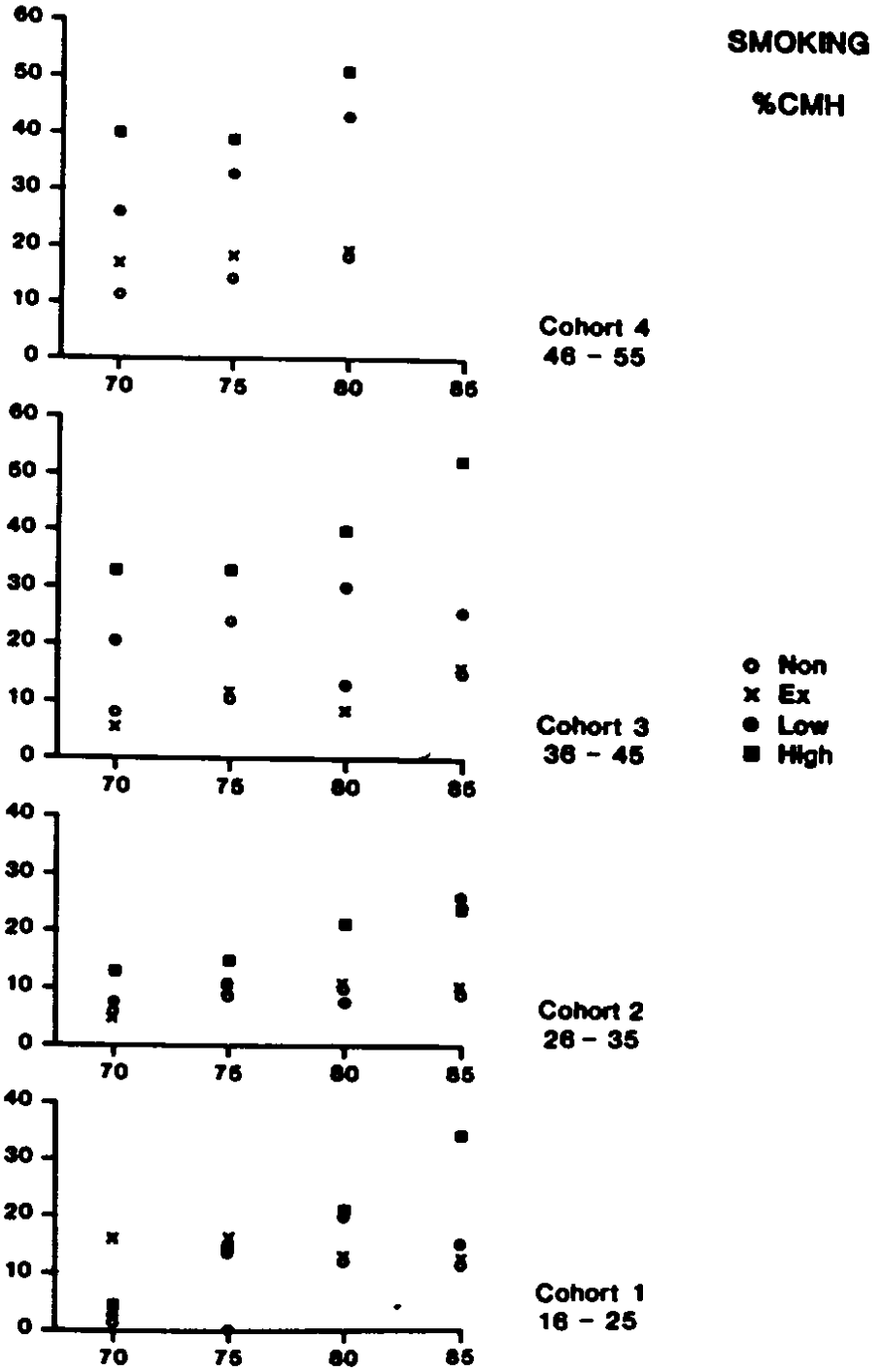

Figure 2. Development of chronic mucus hypersecretion by age and time related to smoking history.

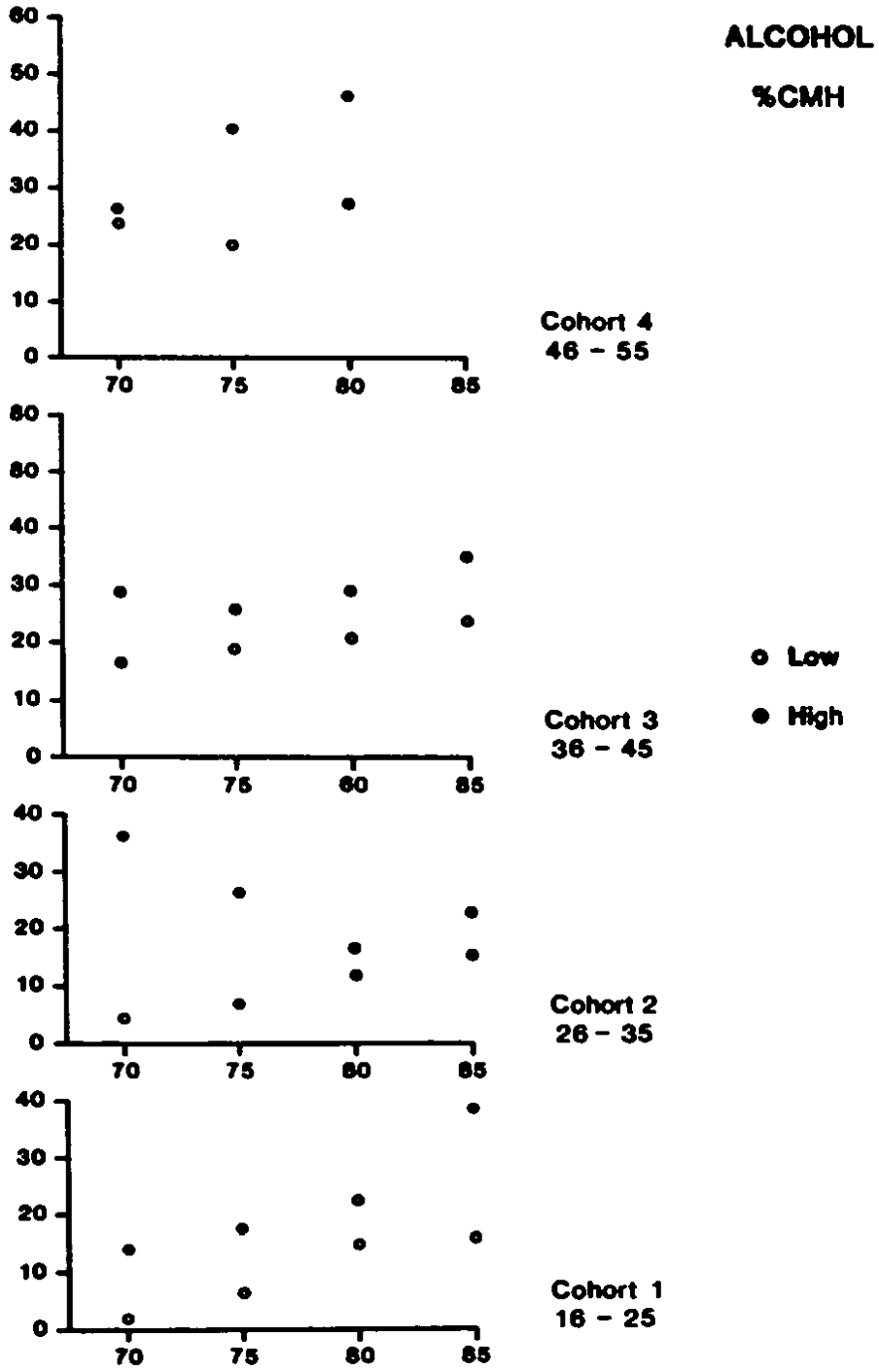

Figure 3. Development of chronic mucus hypersecretion by age and time related to alcohol history.

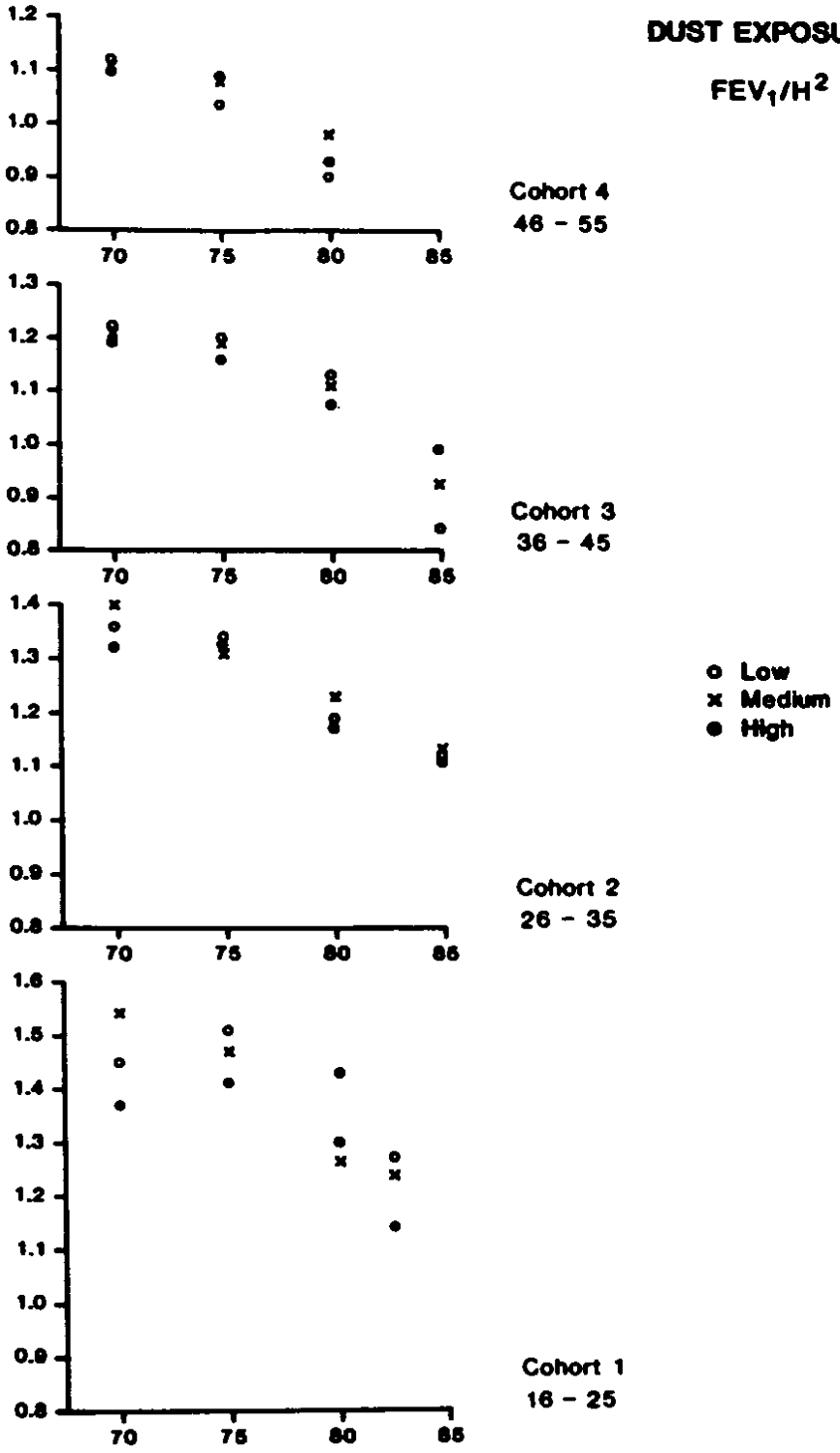

Figure 4. Development of airway obstruction by age and time related to relative dust exposure.

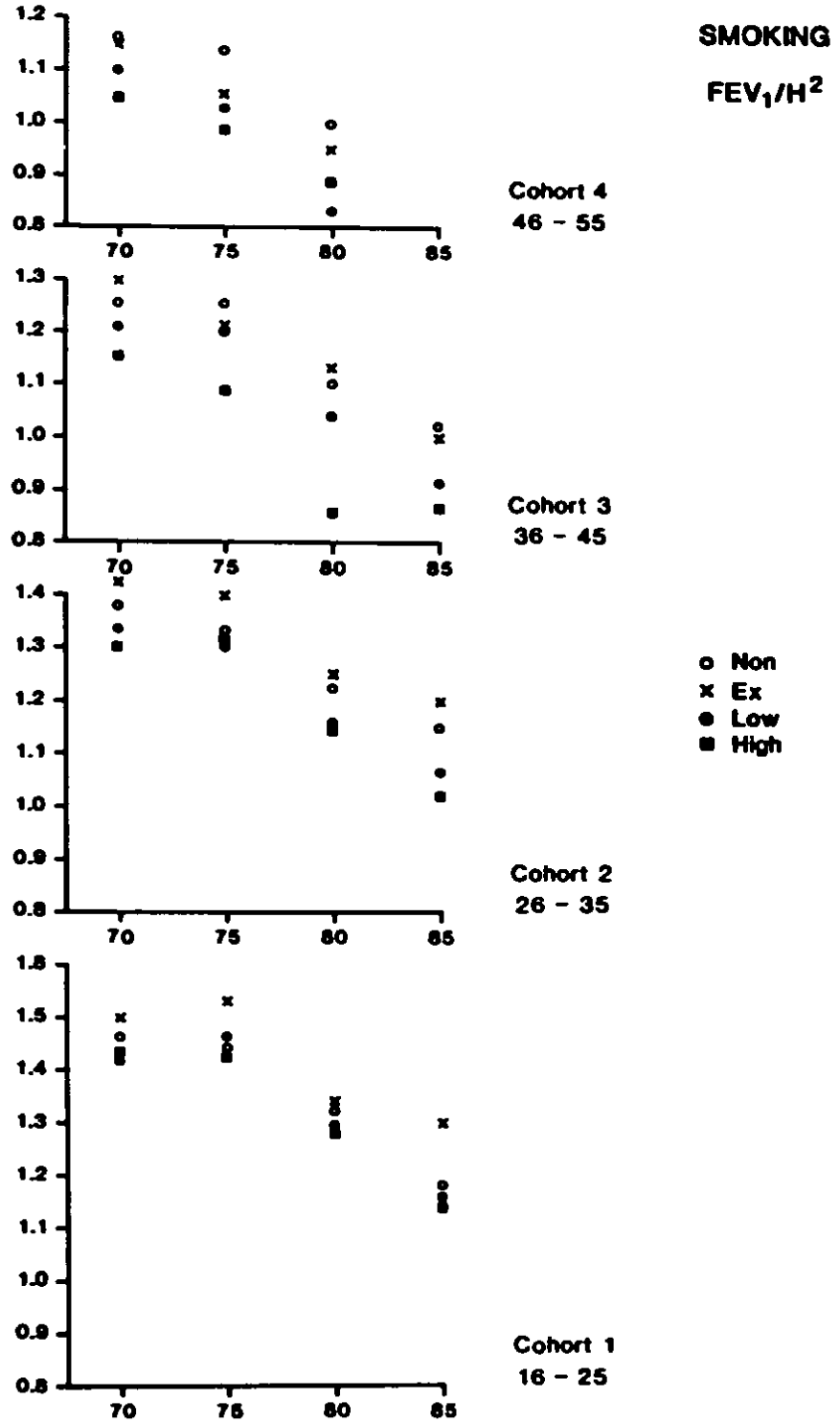

Figure 5. Development of airway obstruction by age and time related to smoking history.

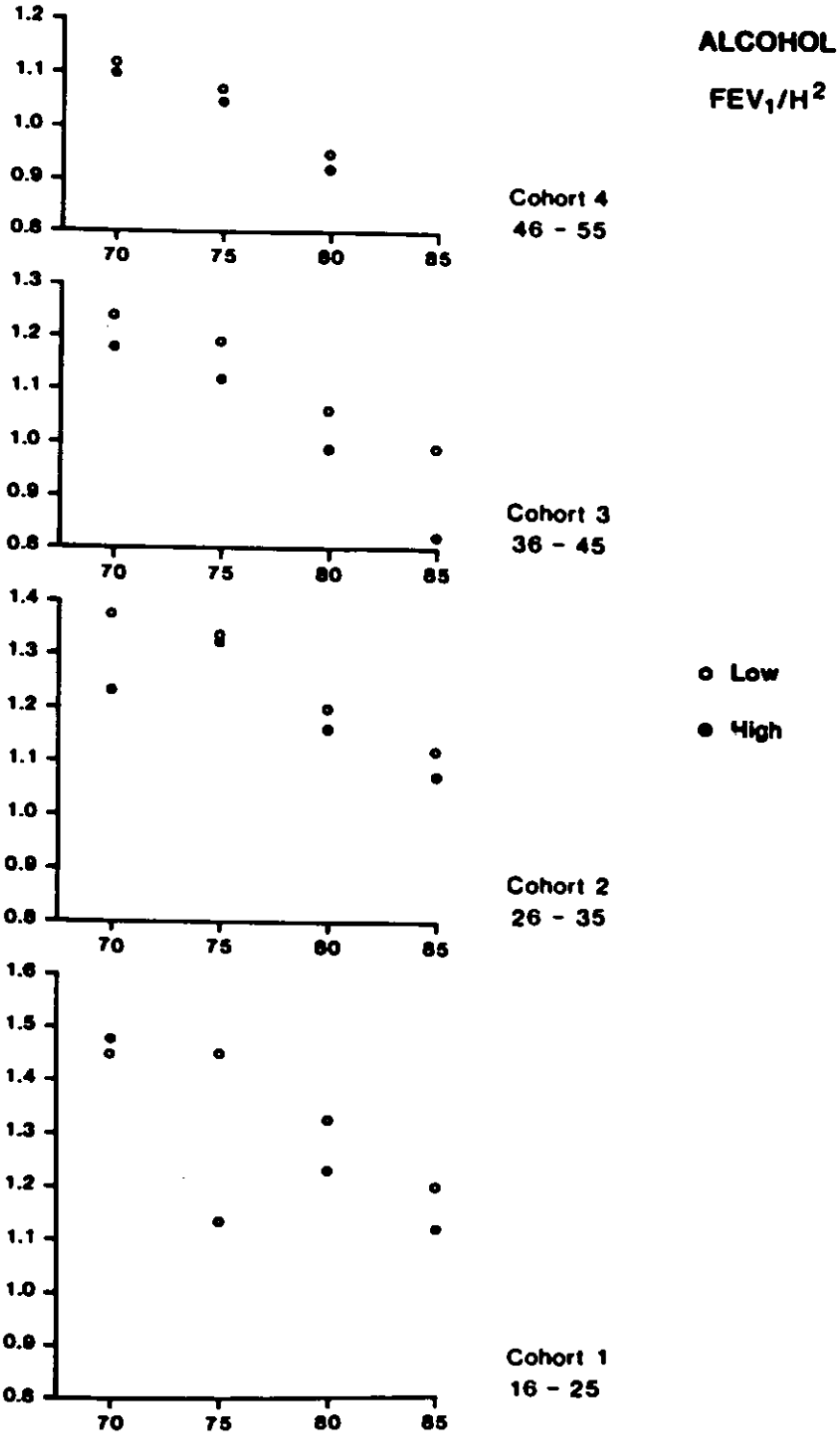

Figure 6. Development of airway obstruction by age and time related to alcohol history.

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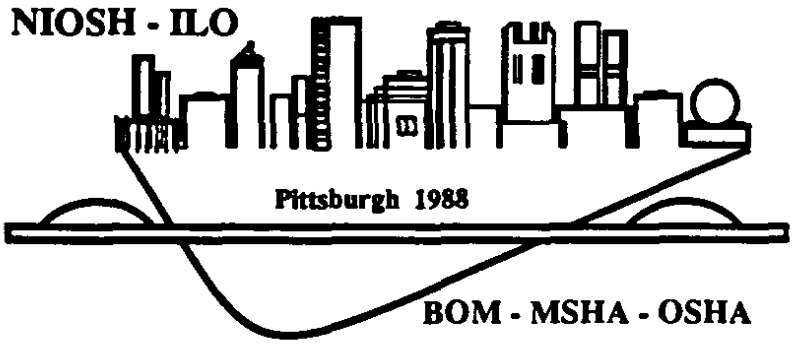

Pittsburgh, Pennsylvania, USA—August 23–26, 1988
Pittsburgh, Pennsylvanie, Etats-Unis—23–26 aout 1988
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September 1990

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DHHS (NIOSH) Publication No. 90-108 Part I