A consideration of risk factors and development of chronic bronchitis in a five-year follow-up study of an industrial population

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SUMMARY A five-year follow-up study in an industrial population showed that the prevalence and development of chest symptoms in men was related mainly to their smoking habits and, to a lesser degree, to age. Mean FEV₁ values were related to age, and decrease in FEV₁ was related to age and smoking habits. The levels of airborne dust and fluorides at the working places were related to the prevalence of chronic bronchitis (CB) symptoms, to the persistence of those symptoms during the five-year period, and to decrease of FEV₁ values during that time. The decrease in FEV₁ was especially noticeable among current smokers. The five-year incidence study showed that particular occupational factors do indeed have a real effect, but their meaning in the development of the CB syndrome is less marked than was expected from the prevalence rates.

The natural history of CB has been explored in many epidemiological surveys of non-industrial populations. However, epidemiological studies undertaken in industrial populations, even if small, provide a better opportunity for measuring the impact of environmental factors on the aetiology of CB. This is a controversial question which has not yet been fully answered, partly because of difficulties in monitoring the environmental exposure of the general population. Ecological studies of CB carried out in industrial groups offer a better opportunity for longitudinal measurements of specific occupational exposure day by day, shift by shift, in all places of work. If the environmental data are compared with the health status of the population under study, it may be possible to assess the relative importance of environmental risk factors and compare them with other known causative factors, such as age and cigarette smoking.

The purpose of this study was to compare the effect of age and smoking on the occurrence of chronic nonspecific respiratory diseases with that of conditions in the occupational environment. The population studied was a group of male workers at a fertiliser factory in Cracow, where prospective epidemiological research has been carried out since 1968. In the factory an inorganic fertiliser called Supertomasine is produced. The technological process depends on the agglomeration in kilns of the proper proportions of apatite mixture, calcine soda, and sand. The workers are exposed to dust and to chemical irritants, mainly fluorides.

Methods and material

The assessment of the health status of the population under study included standardised interviews and spirometric and anthropometric measurements. The questionnaire was based on the Medical Research Council questionnaire for studies of chronic nonspecific respiratory diseases. All interviews were conducted by specially trained lay interviewers. According to the criteria adopted in many epidemiological studies, CB was diagnosed when productive cough was present on most days during at least three consecutive months in the year and for not less than two years.

The persons examined underwent spirometric testing in the sitting position without a nose-clip. After five satisfactory single breath tests had been performed, the maximal effort was selected and the measurements of FEV₁ were corrected to body temperature, pressure, and saturated (BTPS). To evaluate lung function, the decrease in FEV₁ after five years of follow-up was used. This lung function index was calculated according to the formula

$$2X \left(\frac{x_1 - x_2}{x_1 + x_2} \right) \times 100$$

where x_1 = maximal FEV₁ in 1968 and x_2 = maximal FEV₁ in 1973.

The first cross-sectional field study was carried out in 1968 in a group of 248 workers (93% of the total workforce of the factory). Five years later, the examinations were repeated on 197 persons using the

Table 1 Calculations of rates from cross-sectional and prospective observations

1973	Without symptoms	Cough and/or phlegm (not chronic)	CB symptoms	Total
1968				
Without symptoms	a	b	c	a+b+c
Cough and/or phlegm (not chronic)	d	e	f	d+e+f
CB symptoms	g	h	i	g+h+i
Total	a+d+g	b+e+h	c+f+i	N
CB-68 = (g+h+i)/N CB-73 = (c+f+i)/N CB-68/73 = i/N Five-year incidence of CB symptoms = (c+f)/(a+b+d+e) Five-year remission of CB symptoms = (g)/(g+h+i)				

same methods. In this re-examined group, only 186 technically good spiograms were found. The workers who were not examined a second time were slightly older than those who were. There were no marked differences of spirometric values between the two groups.

In the analysis of the data on the health status of the workers examined, the following indices were taken into account:

Prevalence rate of CB in 1968—CB-68.

Prevalence rate of CB in 1973—CB-73.

Prevalence rate of CB in 1968 and 1973—CB-68/73.

Incidence rate of new CB symptoms in the five-year period.

Remission rate of CB symptoms in the five-year period.

These indices were calculated according to the formula presented in Table 1.

The statistical significance of the differences between groups for CB-68/73 and incidence rates was calculated by z test for proportions with a known standard. The probability that a number of CB symptoms would disappear in a five-year period was estimated from the formula for the binomial distribution (Table 1).

Measurements of environmental factors (airborne dust and chemicals, that is, fluorides in solid and gaseous forms) were taken in the factory in two series, during warm and cold seasons. Each series of measurements was taken from Monday to Sunday for an entire day and night at each working place during each shift. Analysis of variance was used for the final classification of working places according to the level of concentrations of both dust and fluorides. Table 2 presents the classification of all places of work in relation to airborne pollution levels.

Results

In 1973 the proportion of those with CB symptoms was slightly smaller than in 1968; this could be explained by an appreciable increase in ex-smokers

Table 2 Classification of all working places in the factory in relation to levels of air pollution

	Category of working place		
	I	II	III
Dust concentrations mg/m ³	5.7	7.5	41.0
Fluorides in solid form mg/m ³	0.06	0.17	0.25
Fluorides in gaseous form mg/m ³	0.03	0.03	0.05

during that period—from 6.1% in 1968 to 16.2% in 1973. The prevalence of CB symptoms in 1968 and 1973 increased with age in those under study, and symptoms were also closely related to smoking habits. In the group of non-smokers the prevalence of CB was half as large in 1973 as in 1968. In the group of current smokers the prevalence of CB symptoms was only slightly lower in 1973 than in 1968. In the oldest persons, CB symptoms occurred more often in 1973 than in 1968; in the youngest, they occurred less frequently. The probability of persistence of CB symptoms in all those in the study CB-68/73, the incidence of new CB symptoms during the period of five years, and the remission rate of these symptoms, were all related to age and smoking habit (Tables 3 and 4).

Mean FEV₁ values were slightly lower in 1973 than in 1968 in the entire group of employees. The smoking group, which had a higher mean FEV than

Table 3 Prevalence of CB symptoms and dynamics of CB in relation to age

	Total n = 197 %	Age in 1968		
		19-40 n = 97 %	41-50 n = 39 %	51-70 n = 61 %
CB-1968	24	21	28	28*
CB-1973	22	15	26	31
CB-68/73	14	10	13	20
Incidence	11	6	18	16
Remission	21	20	18	23

Statistical significance of a difference in proportion between one age group and the proportion in the 19-40 age group: * P<0.05 ** P<0.01.

Table 4 Prevalence of CB symptoms and dynamics of CB in relation to smoking

	Total n = 197 %	Smoking habit in 1973		
		Non-smokers n = 29 %	Ex-smokers n = 32 %	Current smokers n = 136 %
CB-1968	24	14	16	29**
CB-1973	22	7	16	27**
CB-68/73	14	3	6	18**
Incidence	11	4	11	14*
Remission	21	50	40	15**

Statistical significance of a difference in proportion between a smoking category and the proportion in non-smokers: * P<0.05 ** P<0.01.

the non-smoking group, was younger and shorter compared with the non-smokers. The decrease in FEV₁ in the five-year period was faster in older men than in young men and in current smokers than in non-smokers, but the differences were not statistically significant (Table 5).

Respiratory symptoms for the different categories of working places were compared in the contrasting environments. It should be noted that the mean age of workers and the proportion of current smokers among those employed at the two categories I and III were similar. However, the results within different groups of workers exposed to different levels of air pollution were adjusted to allow for age and smoking habit. The prevalence of CB in 1968 and 1973 in those employed at working places in category III, which were the most polluted, was twice as high as in those employed in places assigned to category I. The probability of persistence of CB symptoms during the five-year period (CB-68/73) in men employed at category III working places was three times as high as in those employed at category I places. The prevalence of CB symptoms in 1968 and 1973 and also the probability of persistence of those symptoms

(CB-68/73) in the workers employed at the most polluted sites in the factory was significantly higher than for any of the age or smoking habit groups shown in Tables 3 and 4. The probability of new cases of CB was only weakly related to the level of working place pollution (Table 6).

In the analysis of the decreased rate of FEV₁ the adjusted values for age and height based on the multiple regression equation were used (Table 7). The decrease of FEV₁ during the period of five years in the group working at places in category III was faster than in any other group tabulated according to air pollution and smoking habits. There was no definite relationship between the level of pollution at the working places and the average decrease of FEV₁ during the period of five years in the groups of non-smokers and ex-smokers.

Discussion

Prevalence data show a very substantial excess of CB cases in men working in category III of air pollution compared with those working in categories I and II. There was good agreement between prevalence rates of CB and environmental contrasts between all three categories of air polluted places. Higher prevalence of CB could be caused by other factors such as selection of the men who chose to work in polluted areas; however, this is unlikely.

The five-year incidence study provided evidence that the particular occupational factors do indeed have a real effect, but their meaning in the development of the CB syndrome is less marked than was expected from the prevalence rates. The low ratio observed between incidence rates of CB cases in categories III and I of air pollution does not necessarily indicate the real strength of these factors. It is probable that CB symptoms appeared earlier in susceptible workers before our study began than among others who were more resistant. So the

Table 5 FEV₁ measurements in 1968 and 1973 by age and smoking habit, standardised for age and height*

		Total n = 186	Age in 1968		Smoking habit in 1973		
			50 and under n = 131	51 and over n = 55	Non-smokers n = 27	Ex-smokers n = 30	Current smokers n = 129
FEV ₁ in 1968	Mean	3.6	4.0	2.9	3.6 (0.91)*	3.7 (0.94)*	3.7 (0.89)*
	SD	0.7	0.7	0.7	0.7	0.7	0.7
FEV ₁ in 1973	Mean	3.5	3.8	2.6	3.4 (0.88)*	3.6 (0.91)*	3.6 (0.86)*
	SD	0.7	0.8	0.7	0.8	0.8	0.7
Decrease in FEV ₁	Mean	6%	4%	9%	3%	5%	7%
	SD	14.1	10.7	19.7	13.2	12.8	14.5

* Adjusted FEV₁ index for age and height was calculated according to the formula developed by Khosla (1971) = $\frac{\text{FEV}_1 \times \text{age}^{\frac{1}{2}}}{\text{ht}^2}$

and nomograms worked out by Jędrychowski and Ksiezzyk (1973).

Table 6 Prevalence of CB symptoms and dynamics of CB by category of air pollution in the working place adjusted for age and smoking habits

	Total n = 197 %	Category of air pollution		
		I n = 143 %	II n = 27 %	III n = 27 %
CB-1968	24	21	19	46
CB-1973	22	19	18	35
CB-68/73	14	11	14	30
Incidence	11	11	9	13
Remission	21	20	*	22
Relative risk**	—	1.0	0.8	1.2

* Not calculated because of small number of persons in the group.

**Relative risk calculated in relation to the group of workers in category I.

Table 7 Mean FEV₁ decrease related to smoking habits and air pollution category of the working place, adjusted* for age and height

		Category of air pollution		
		I	II	III
Non-smokers	n	20	3	4
	mean	2.7%	5.3%	2.4%
	SD	3.8	2.6	2.1
Ex-smokers	n	19	6	3
	mean	5.9%	5.9%	5.8%
	SD	2.4	6.3	3.7
Current smokers	n	100	14	17
	mean	4.3%	10.2%	13.1%
	SD	1.1	3.6	5.9

*Adjusted values were calculated to standard age (40 years) and height (170 cm) by multiple regression equation.

$$[y = -0.297 + 0.002(\text{age}) + 0.001(\text{height})]$$

conclusion about the slow effect of this particular environment might have been misleading if it had been based only on incidence rates. It is also necessary to take into account the fact that the incidence rates of CB, when the diagnostic criteria are based on interviews, are subject to some uncertainty. However, in this particular study, the incidence and remission rates appeared to represent nothing more than observer variation in the eliciting of CB symptoms. The true change of symptoms, especially in relation to smoking, could be supported by statistical analysis.

Comparing the environmental survey data with CB symptoms (prevalence and incidence) it appears that it is the total dust rather than the fluoride content that is relevant to these symptoms. Analysis of spirometric data showed that the decrease of FEV₁ was faster in categories II and III than in category I. So it appears that it is fluoride content rather than the total dust that is relevant to deterioration in lung function. Also the absolute values of spirometric readings showed rather similar contrasts between pollution categories on each occasion.

Although several prospective studies have been carried out on chronic obstructive lung disease in various industrial populations, they hardly dealt with the impact of industrial pollution at the place of work in comparison with other risk factors. The data of this study would be consistent with the results of the prospective studies by Fletcher *et al.* in London and Sawicki *et al.* in Cracow. This study confirmed that CB symptoms and faster lung function deterioration were caused predominantly by smoking, with air pollution playing a contributory role. However, it showed that the combined effect of air pollution and smoking was stronger than the single effect of smoking. The validity of the conclusions drawn in this respect is rather limited, since there was a substantial variation in the spirometric measurements in the prospective study performed, and a very small number of persons under observation. In spite of the lack of significant differences of spirometric indices with regard to smoking and environmental hazards, the data presented have very clear biological meaning and importance.

In this paper an attempt has also been made to compare the data on CB from cross-sectional studies with the data from prospective studies for decision-making in health care and prevention programmes of industrial populations. We have to agree that prospective studies are very important in aetiological research because it is possible to measure in a direct way the relative risk between exposed and non-exposed groups. It is also easy to find the nominator and denominator to calculate the incidence rates. However, there are some problems with so-called 'dropouts' as a result of turnover of workers. Men often change their places of work when their health has deteriorated. Prospective studies take a lot of time, and are very lengthy when dealing with chronic diseases; also, it is very difficult to maintain the same standard techniques of measurement for a long time. Such studies are not worthwhile unless there is a large number of observations in the exposed and non-exposed groups and the population is relatively stable for a long time. Cross-sectional study of CB appeared to be useful for measuring environmental risk factors when confounding variables were controlled and taken into account in the final analysis of the data. So it seems that prevalence study can provide a reasonably sound basis for decision-making in the health care and prevention programmes of industrial populations.

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