IV. CHRONIC RESPIRATORY DISEASE IN AN INDUSTRIAL TOWN: A NINE-YEAR FOLLOW-UP STUDY. PRELIMINARY REPORT.

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In 1957 the British Medical Research Council's Pneumoconiosis Research Unit carried out a survey of chronic respiratory disease in Staveley, England. Staveley is an industrial town whose 18,000 inhabitants are engaged mainly in mining, foundry, chemical, and railway work. A random sample of men, stratified by age and occupation was seen (Higgins, et al., 1959).[2] There were two age groups, 25-34 and 55-64 years, and four occupation groups: miners and ex-miners, foundry and ex-foundry workers, other dusty and non-dusty workers. Ninety-two per cent of the 1957 sample was seen; 8 per cent refused. Respiratory symptoms and ventilatory lung function were related to occupational exposure to dusts and fumes and to smoking habits. The prevalence of symptoms was higher and lung function lower in miners and ex-miners and men exposed to chemical fumes than in men who had worked only in nondusty jobs. A higher prevalence of symptoms and lower lung function was also observed in smokers compared with non-smokers.

It is often difficult to interpret associations found in a cross-sectional study of this kind. For example, an individual may be found to have low lung function. Is this because his lung function has always been low or is it because it has undergone an exceptional decline? Again the average lung function of a group of people may be found to be low. This could be because of an exceptional decline in lung function of the group as a whole, but could also be due to selection affecting the composition of the group. Selection of persons with low lung function into the group or loss of those with high function from it could equally explain the low value. Precisely similar considerations apply mutatis mutandis to a high average value. A cross-sectional study provides little objective information about the natural history of disease and no direct means of assessing the prognostic significance of respiratory symptoms or low lung function. The onset, course, progression, and remission of symptoms and the outcome of disease have been surprisingly neglected in the field of respiratory disease. Most relationships between possible etiological factors and respiratory disease have been based on prevalence and few surveys have considered incidence, course and outcome—a fact that was noted in the Report of the Surgeon General's Committee on Smoking and Health, 1963.[5] For these reasons follow-up of the men seen in the original sample was carried out. The study was originally conceived as a simple follow-up of the sample seen in 1957. We realized, however, that to differentiate between the effects of aging and the effects of changes in the environment over a period of time, such a simple study would be inadequate and we should have to include a new cross section of the town. The study was therefore enlarged to include a new census and two new age stratified random samples, one also stratified by occupation

and comparable with that studied in 1957 and the other representative of the 1966 population.

Preliminary Study in 1965

A preliminary investigation was made to see if the follow-up was practicable. One per cent of the young and 23 per cent of the old had died; 8 per cent of the young and 5 per cent of the old had emigrated from the area. Ninety-one per cent of the young and 73 per cent of the old, therefore, were still living in the area. We decided that this proportion justified us in proceeding with the follow-up.

Census and New Sample

A new census of Staveley was carried out by Market Research Interviews Limited between May 1 and 18, 1966. The information obtained was: (1) name and address; (2) date of birth; (3) present occupation; and (4) past employment in mining, foundry, other dusty or chemical work.

From this total population two interlocking samples were selected: (1) an age stratified sample consisting of one in three men drawn at random from each ten-year age group from 25 to 74 years, and (2) a weighted sample stratified by age and occupation. This was obtained by continuing sampling in each age and occupation group until 50 men had been chosen in each decade and work subgroup.

Main Study in 1966

Methods and Procedure

All men in the main study were seen between June 20 and July 28, 1966. The great majority was seen by appointment at a center in Staveley. About 3 per cent who could not or would not come to the center were seen in their homes. Transport to and from the center was provided for the majority of the men. The methods used are shown in Table 1.

The questionnaire was basically similar to that used in 1957. This was a prototype of the Medical Research Council's Respiratory Symptoms Questionnaire (1960)[6] which consists of standardized questions about cough, phlegm, wheezing, chest illness and so on—and smoking habits. Questions about chest pain and heart attacks were also included.

Occupational and domiciliary histories were taken. For members of the follow-up group these histories covered the past nine years from 1957. For members of the new samples they were throughout life.

The three-quarter second and one second forced expiratory volumes (FEV) and the forced vital capacity were measured (Medical Research Council 1965).[1]

Table 1—Chronic respiratory disease in Staveley

Methods
1. Questionnaire
respiratory symptoms and illnesses
chest pain and heart attacks
smoking habits
occupational history
domiciliary history
2. Measurements of ventilatory lung function
$FEV_{(.75)}$
$FEV_{(1.0)}$
FVC
3. Physical measurements
sitting and standing heights in centimeters
weight in kilograms
4. Chest x-ray 14"x17" in PA projection
5. Qualitative and quantitative assessment of sputum
6. Blood pressure (men over 35 years)
7. 12 lead resting electrocardiogram (men over 35 years)

Standing and sitting heights were measured to the nearest centimeter and weight to the nearest half kilogram.

A postero-anterior chest x-ray was taken. As far as possible the 1966 radiographic technic was designed to produce a film as similar as possible to that taken in 1957.

Each man was asked to cough into a bottle all the sputum he brought up from his chest during the first hour after getting up. The sputa were inspected daily by Dr. Gilson and myself. Quantity was measured and quality recorded as recommended by Miller and Jones (1963).[4] A random sample of the 20 per cent who failed to return their sputum bottles was followed up and a specimen bottle obtained from nearly every one of them.

All men aged 35 years and over in the new sample had a 12-lead resting electrocardiogram followed by a measurement of the arterial blood pressure. After the first few days all the men in the follow-up survey also had ECGs and blood pressure measurements.

The questionnaires and lung function tests were administered by four physicians: Dr. J. C. Gilson, Dr. B. Ferris, Dr. M. Higgins, and myself. Subjects were randomly allocated to each of us. In 1957 Dr. Gilson and I were the only two interviewers. We each saw a random half of the whole sample.

Clinical reading of chest x-rays and ECGs was carried out during the course of the survey. Any man who needed further medical investigation or treatment or whose x-ray suggested he might obtain a pension for pneumoconiosis was advised, and his doctor informed.

Systematic reading of the chest x-rays from the present and the earlier survey was carried out independently by Dr. Gilson and myself in Cardiff after the survey in Staveley had been completed. The 2,200 x-rays were classified according to the modification of the International Labour Organisation's Classification (ILO 1958)[3] now being used at the Pneumoconiosis Research Unit.

Follow-up of the Wives

Included in the 1957 survey were 334 wives of the men in the older age group. They were seen in their homes by Dr. C. H. Wood, a member of the survey team. We decided to follow up this group of women. Those who were not known to have died were randomized into three groups and visited in their homes by Drs. M. Higgins, Lockshin, and myself before the main survey started. We completed a respiratory symptoms questionnaire and measured standing height and peak expiratory flow rates for each woman. We used the Wright peak flow meter which was the instrument used in the 1957 sample.

Results

Table 2 shows what had happened to the men in the original sample by the time of the follow-up in 1966: 102 (13.5 per cent) had died; 42 (5.6 per cent) had left the area; 18 (2.4 per cent) refused or were excluded; and 594 (78.6 per cent) were seen again.

Mortality in Relation to Age, Occupation, X-ray Category of Pneumoconiosis, and $FEV_{.75}$

Of the 25-34 age group 1.6 per cent had died and 7.3 per cent had left the area; 24.8 per cent of the 55-64 age group had died and 3.8 per cent had left the area. All six deaths in the younger men were in those who worked or had worked in dusty occupations. In the older men the proportion of miners and ex-miners who died was similar to that of the nondusty workers. An insignificantly higher proportion of deaths occurred among foundry workers. This excess mortality in the foundry workers is entirely accounted for by the ex-

Table 2—Status in 1966 of men seen in Staveley in 1957, by age and occupation in 1957

Age in 1957 (years)	Occupation in 1957	No. seen in 1957	Status in 1966							
			Dead		Left area		Lapse		Seen	
			No.	%	No.	%	No.	%	No.	%
25–34	Nondusty	114	0	—	13	11.4	1	0.9	100	87.7
	Miners and ex-miners	94	1	1.1	2	2.1	1	1.1	90	95.7
	Foundry and ex-foundry	91	2	2.2	5	5.5	4	4.4	80	87.9
	Other dusty or chemical	70	3	4.3	7	10.0	2	2.9	58	82.9
	All occupations	369	6	1.6	27	7.3	8	2.2	328	88.9
55–64	Nondusty	81	18	22.2	8	9.9	3	3.7	52	64.2
	Miners and ex-miners	149	32	21.5	4	2.7	5	3.4	108	72.5
	Foundry and ex-foundry	65	19	29.2	2	3.1	1	1.5	43	66.2
	Other dusty or chemical	92	27	29.3	1	1.1	1	1.1	63	68.5
	All occupations	387	96	24.8	15	3.8	10	2.6	266	68.7
All ages	All occupations	756	102	13.5	42	5.6	18	2.4	594	78.6

cess in foundry workers with pneumoconiosis, 42.9 per cent of whom were dead in nine years compared with 24.0 per cent of the nondusty workers. There was no difference in the proportion of deaths in miners with and without pneumoconiosis (Table 3). Though the numbers of foundry workers with pneumoconiosis was small, the excess deaths suggest that for an equivalent degree of pneumoconiosis foundry dust may be more dangerous than coal mine dust.

In both age groups those exposed to other dusts or chemical fumes or both had higher mortality rates than the rest of the population. This is in line with our findings in 1957. At that time both miners and ex-miners and foundry and ex-foundry workers who had also worked in other dusts were found to have lower lung function than those who had worked only in mining or foundry work. In addition, coke oven, furnace, and chemical workers appeared to be particularly disabled by respiratory disease.

The mean $FEV_{.75}$ values in 1957 for those who died and for those who were seen in 1966 are shown in Table 4. The lower average values of those who died are striking and indicate that the FEV has considerable prognostic implications.

Change in $FEV_{.75}$ in Relation to Age, Occupation, and X-ray Category of Pneumoconiosis

Mean $FEV_{.75}$ and change in $FEV_{.75}$ by age and occupation are shown in Table 5. The mean values for the whole sample examined in 1957 may be compared with the values for those members of the 1957 population who were

Table 3—Mortality in nine years by x-ray category of pneumoconiosis in 1957, miners and ex-miners and foundry and ex-foundry workers aged 55-64 years, Staveley

Occupation in 1957	X-ray category of pneumoconiosis	No. seen in 1957	Dead by 1966	
			No.	%
Miners and ex-miners	0	96	21	21.9
	123	53	11	20.8
	PMF	0	—	—
	All	149	32	21.5
Foundry and ex-foundry workers	0	50	12	24.0
	123	14	6	42.9
	PMF	1	1	100.0
	All	65	19	29.2

seen again in 1966. The mean values of FEV in 1957 and in 1966 are given for those men who were examined twice. The average $FEV_{.75}$ is the sum of the two measurements in 1957 and 1966 divided by two. The mean changes in $FEV_{.75}$ over nine years and the average annual changes (or falls) are also presented. As is well known, the absolute values are higher in the young than the old. It appears from this study that the rate of decline may also be slightly higher in older than in younger people. This is at variance with earlier findings (Higgins and Oldham 1962) in the Rhondda where a decline of 0.0466 liters per year appeared independent of age. Here the decline in men aged 25-34 was 0.034 liters per year; in men aged 55-64 it was 0.045 liters per year.

In both age groups the mean FEV over the nine years was higher in the men who had worked only in nondusty occupations than in the other groups. The nondusty workers also tended to have lower average rates of decline of

Table 4—Mean $FEV_{.75}$ in 1957 by status in 1966

Age in 1957	Occupation in 1957	Mean FEV.75 in 1957					
		Dead by 1966			Seen in 1966		
		No.	Mean	Stand. dev.	No.	Mean	Stand. dev.
25–34	Nondusty	—	—	—	100	3.55	0.57
	Miners and ex-miners	1	3.26	0.00	90	3.36	0.53
	Foundry and ex-foundry	2	4.17	0.66	80	3.49	0.55
	Other dusty or chemical	3	3.63	0.59	58	3.46	0.61
55–64	Nondusty	18	1.77	0.73	52	2.36	0.58
	Miners and ex-miners	32	1.98	0.50	108	2.22	0.61
	Foundry and ex-foundry	19	1.65	0.50	43	2.27	0.49
	Other dusty or chemical	27	1.45	0.69	63	2.27	0.58

FEV over the nine years than those who worked in dust or fumes. However, there are several exceptions to this and all the differences for absolute values and change are small. The effect of mortality on the population is apparent in this table. Among the younger men those seen again had very similar mean FEV values to the whole group; but among the older men, for every occupation group those who were seen in 1966 had higher values in 1957 than the rest of the sample. This of course follows naturally from the earlier observation that those who died had lower mean FEV values than those who survived.

The effect of radiological category of pneumoconiosis is shown in Table 6. The means and declines of FEV in miners with and without simple pneumoconiosis are almost identical. Among the foundry workers, however, those with simple pneumoconiosis had lower mean values and declined more over the nine years.

Mortality in Relation to Smoking Habits

Mortality in the nine years from 1957-1966 is presented for nonsmokers, light and heavy smokers, and ex-smokers in Table 7. The classification is based on smoking habits in 1957, not on average habits over the preceding ten years which were used in the original publication. Smokers include all users of tobacco—cigarettes, pipe, and cigar smokers together—and the subdivision into light and heavy is based on the total amount of tobacco used regardless of the type. In the older age group the death rate for smokers was about twice that for nonsmokers regardless of the amount smoked. Ex-smokers resembled nonsmokers in their mortality experience.

Change in $FEV_{.75}$ in Relation to Smoking Habits

The mean FEV and change in FEV over the nine years by age and smoking habits are shown in Table 8.

Table 5—Mean $FEV_{.75}$ and change in $FEV_{.75}$ by age and occupation in 1957

Age in 1957	Occupation in 1957	Complete sample 1957			Those sampled in 1957 and seen in 1966					Mean FEV over the nine years	Mean change in the nine years	Mean annual decline
					1957			1966				
		No.	Mean	Stand. dev.	No.	Mean	Stand. dev.	Mean	Stand. dev.			
25–34	Nondusty	114	3.57	0.55	100	3.55	0.57	3.26	0.58	3.41	0.29	0.032
	Miners and ex-miners	94	3.36	0.52	90	3.36	0.53	3.08*	0.50	3.22	0.28	0.031
	Foundry and ex-foundry	91	3.50	0.56	80	3.49	0.55	3.19	0.60	3.34	0.30	0.033
	Other dusty or chemical	70	3.48	0.59	58	3.46	0.61	3.10	0.68	3.28	0.36	0.040
55–64	Nondusty	81	2.25	0.68	52	2.36	0.58	1.99†	0.61	2.18	0.37	0.041
	Miners and ex-miners	149	2.17	0.61	108	2.22	0.61	1.75‡	0.69	1.99	0.47	0.052
	Foundry and ex-foundry	65	2.10	0.59	43	2.27	0.49	1.93§	0.52	2.10	0.34	0.038
	Other dusty or chemical	92	2.03	0.72	63	2.27	0.58	1.90	0.68	2.09	0.37	0.041

* Based on 89/90.
† Based on 50/52.
‡ Based on 107/108.
§ Based on 42/43.

Table 6—Mean $FEV_{.75}$ and change in $FEV_{.75}$ by age, occupation, and x-ray category of pneumoconiosis in 1957

Age in 1957	Occupation in 1957	X-ray category	Complete sample 1957			Those sampled in 1957 and seen in 1966					Mean FEV over the nine years	Mean change in the nine years	Mean annual decline
						1957			1966				
			No.	Mean	Stand. dev.	No.	Mean	Stand. dev.	Mean	Stand. dev.			
25–34	Miners and ex-miners	0	89	3.34	0.52	85	3.34	0.53	3.06*	0.50	3.20	0.28	0.031
		123	5	3.75	0.26	5	3.75	0.26	3.48	0.26	3.62	0.27	0.030
		Total	94	3.36	0.52	90	3.36	0.53	3.08*	0.50	3.22	0.28	0.031
55–64	Miners and ex-miners	0	96	2.17	0.62	67	2.22	0.61	1.76†	0.67	1.99	0.46	0.051
		123	53	2.17	0.59	41	2.22	0.61	1.74	0.71	1.98	0.48	0.053
		Total	149	2.17	0.61	108	2.22	0.61	1.75†	0.69	1.99	0.47	0.052
	Foundry and ex-foundry	0	50	2.13	0.64	35	2.31	0.53	1.98	0.55	2.15	0.33	0.037
		123	14	2.05	0.36	8	2.10	0.21	1.67‡	0.25	1.89	0.43	0.048
		PMF	1	1.21	0.00	0	—	—	—	—	—	—	—
		Total	65	2.10	0.59	43	2.27	0.49	1.93‡	0.52	2.10	0.34	0.038
	Other dusty or chemical	0	79	2.05	0.73	55	2.28	0.59	1.90	0.68	2.09	0.38	0.042
		123	12	1.85	0.60	7	2.15	0.47	1.71	0.67	1.93	0.44	0.049
		PMF	1	2.91	0.00	1	2.91	0.00	2.77	0.00	2.84	0.14	0.016
		Total	92	2.03	0.72	63	2.27	0.58	1.90	0.68	2.09	0.37	0.041

* Based on 84/85, total based on 89/90.
† Based on 66/67, total based on 107/108.
‡ Based on 7/8, total based on 42/43.

Table 7—Mortality in nine years by age and smoking habits in 1957, Staveley

Age in 1957	Smoking habits in 1957	Seen in 1957 No.	Dead by 1966 No.	Dead by 1966 %
25–34	Nonsmokers	56	1	1.8
	Smokers:			
	1–14 gm	129	1	0.8
	15 gm and over	150	3	2.0
	Ex-smokers	34	1	2.9
	Total	369	6	1.6
55–64	Nonsmokers	29	4	13.8
	Smokers:			
	1–14 gm	158	48	30.4
	15 gm and over	135	35	25.9
	Ex-smokers	64	9	14.1
	Total	386	96	24.9

As we showed in our original paper, smokers had a lower mean FEV than nonsmokers and this was so in the 25-34 as well as the 55-64 age group. The mean values over the nine years for the heavier smokers were somewhat lower than those for the lighter smokers in both young and old. While this had been so for the young group in 1957 we did not find any appreciable difference between the two mean values for the older men. The average decline over the nine years was lowest in the nonsmokers, slightly greater in the ex-smokers, and greatest in the smoking groups. In the 25-34 group there was little difference in the rate of decline between the light and heavy smokers, but in the 55-64 group the decline was greater in the heavy than in the lighter smokers.

Comment

The analysis to date has been based on a broad classification of occupation and smoking habits in 1957. The information available permits a much more detailed breakdown. For example, we intend to compare face workers with other workers in mining and moulders, fettlers and pattern makers among foundry workers. We are also curious to see if the high prevalence of respiratory disease, which we recorded among chemical workers in 1957, is still present. Similarly we shall carry out a more detailed analysis of smoking by type and lifetime duration.

We intend to consider occupation and smoking habits during the past nine years. We are particularly interested in whether or not changes in FEV are related to changes in exposure to dust and fumes and to changes in smoking during this time. Such changes should indicate if changing from a dusty to a nondusty job or giving up smoking is likely to lead to any improvement in lung function.

We are equally interested in identifying and quantifying any other factors, such as respiratory symptoms, chest illnesses, residence in different areas within and outside the town, which may play an etiological role in respiratory disability. We have not yet begun to analyze the new cross-sectional survey, which we carried out at the same time as the follow-up and which we hope will

Table 8—Mean $FEV_{.75}$ and change in $FEV_{.75}$ by age and smoking habits in 1957

Age in 1957	Smoking habits in 1957	Complete sample 1957			Those sampled in 1957 and seen in 1966					Mean FEV over the nine years	Mean change in the nine years	Mean annual decline
					1957			1966				
		No.	Mean	Stand. dev.	No.	Mean	Stand. dev.	Mean	Stand. dev.			
25–34	Nonsmokers	56	3.63	0.60	50	3.63	0.63	3.44	0.57	3.54	0.19	0.021
	Smokers:											
	1–14 gm	129	3.53	0.59	120	3.51	0.60	3.18	0.64	3.35	0.33	0.037
	15 gm and over	150	3.38	0.52	127	3.36	0.50	3.02*	0.53	3.19	0.34	0.038
	Ex-smokers	34	3.49	0.45	31	3.52	0.46	3.26	0.48	3.39	0.26	0.029
55–64	Nonsmokers	29	2.53	0.56	24	2.59	0.46	2.30	0.57	2.45	0.29	0.032
	Smokers:											
	1–14 gm	158	2.06	0.71	99	2.22	0.64	1.82†	0.64	2.02	0.40	0.044
	15 gm and over	135	2.10	0.58	93	2.18	0.53	1.69‡	0.64	1.94	0.49	0.054
	Ex-smokers	64	2.24	0.59	49	2.35	0.51	2.02	0.60	2.19	0.33	0.037

* Based on 126/127. † Based on 98/99. ‡ Based on 90/93.

provide us with information on any secular changes that have been taking place in the town.

Summary

In 1957 the British Medical Research Council's Pneumoconiosis Research Unit carried out a survey of chronic respiratory disease in Staveley, an industrial town of some 18,000 inhabitants engaged mainly in mining, foundry, chemical, and railway work, situated in the center of industrial England. A sample of men, stratified by age and occupation was examined. The prevalence of respiratory symptoms was higher and ventilatory lung function lower in miners and ex-miners and men exposed to chemical fumes than in men who had worked only in nondusty jobs. A higher prevalence of symptoms and lower lung function was also observed in smokers compared with nonsmokers.

In 1966 a follow-up study was made of all the men who had been seen in the initial study who were still living in the area. At the same time the opportunity was taken to study a new sample of the town. There were approximately 1,600 men in the old and new samples and over 90 per cent were seen. A questionnaire on respiratory symptoms, smoking habits, and occupation similar to that used previously was used. The three-quarter second and one second forced expiratory volumes and forced vital capacities were measured. A 14 x 17-inch postero-anterior chest radiograph was taken and classified for pneumoconiosis according to the ILO classification (1959).

In the nine years between the first and second survey 102 men had died; the cause of death as given on the death certificate was ascertained wherever possible. The nine-year mortality of the miners and ex-miners in the sample was insignificantly higher than that of the men who had worked only in nondusty

jobs and it was no different in miners with simple pneumoconiosis than in those without. The mortality of the foundry workers was higher than that of the nondusty workers over the same period and was appreciably higher in foundry workers with simple pneumoconiosis. In the 55-64 age group the mortality of smokers from all causes was approximately twice that of nonsmokers or ex-smokers.

The average annual decline in the three-quarter second forced expiratory volume was slightly greater in the older than in the younger men. The decline did not appear to be closely related to occupation. It was, however, appreciably greater in smokers than in nonsmokers or ex-smokers. The results suggest, once again, that smoking is a more important factor in the development of respiratory disability than occupation.

The 1966 stratified sample is being compared with the one seen in 1957 to determine if there has been any secular trend in respiratory symptoms, smoking habits, prevalence of pneumoconiosis or ventilatory lung function.

ACKNOWLEDGMENTS—The authors wish to express their thanks to their colleagues at the Medical Research Council's Pneumoconiosis and Epidemiological Research Units; in particular to Professor A. L. Cochrane for his invariably stimulating and constructive suggestions; to Mr. W. G. Clark for his consistently excellent radiographs; to Mrs. Marjorie McDermott for four exceptionally comparable spirometers, and to the members of the epidemiological and radiological survey teams.

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This paper was presented before a Joint Session of the Epidemiology, Engineering and Sanitation, Maternal and Child Health, Occupational Health, and Radiological Health Sections of the American Public Health Association at the Ninety-Fifth Annual Meeting in Miami Beach, Fla., October 25, 1967.

This study was supported by Grant Number OH 00243-01 from the American Medical Association's Education and Research Foundation Committee for Research on Tobacco and Health.