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RESTRICTIVE PULMONARY DYSFUNCTION DEVELOPING IN COKE OVEN WORKERS

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ABSTRACT

Coke oven workers are known to suffer excessive mortality from malignant and non-malignant respiratory diseases. Early symptoms of overt non-malignant disease have been difficult to detect on cross-sectional analysis. This paper compares spirometric and other lung function tests in coke oven and non-coke exposed workers in the steel industry. Observations of obstructive and a heretofore unreported restrictive dysfunction are discussed. It is shown that while smoking history is a significant factor on cross-sectional analysis for VC, $FEV_{1.0}$, FRC and RV ($p < 0.05$), work place significantly influences the longitudinal observations for all tests but VC.

It is well documented that coke oven workers suffer an excess risk of dying from lung cancer[6,7,14,15]. Other data suggest that these workers are also at an excess risk of developing non-malignant respiratory diseases, such as bronchitis and emphysema[12,16]. These indications of a work place hazard come from mortality studies or cross-sectional surveys, research methods which clarify disease prevalence rates but are less likely to reveal the early development and manifestations of a problem. To obtain an accurate assessment of the early as well as the long term effects of an industrial exposure longitudinal studies are often needed[3,10]. To our knowledge such studies have not been conducted in the steel industry.

To remedy this lack we undertook a longitudinal investigation to determine the amount and kind of malignant and non-malignant respiratory disease present in steel workers occupationally exposed to coke oven emissions. Preliminary analysis of the data collected suggests that workers are developing signs of restrictive as well as obstructive lung disease. This paper reports this heretofore unrecognized observation of a restrictive dysfunction.

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SUBJECTS AND METHODS

In 1975 we initiated a longitudinal study on 700 workers in a local steel mill. Workers in selected work areas have been tested annually. Each year they completed a self-administered respiratory disease questionnaire patterned after the British Medical Research Council form, modified for U.S. populations[9]. Using standardized methods spirometry was performed with a 13.5 liter water-sealed respirometer to measure vital capacity (VC), maximum mid-expiratory flow rate (MMFR), and timed vital capacity as the one second forced expiratory volume ($FEV_{1.0}$)[5]. Functional residual capacity (FRC) was measured by closed circuit helium dilution and residual volume (RV) was calculated in the usual fashion[1]. Sputum samples were obtained for cytological analysis[17]. These results will be reported elsewhere.

Workers who met the following criteria were included in this analysis: if they were consistently employed in the same work area; were currently smoking cigarettes or had never smoked; and had completed the pulmonary function tests in the years 1975 and 1976. Note that ex-smokers were excluded from the present analysis; findings in this group confounded the analysis because of certain uncertainties in their smoking history, the period of abstinence and the variable effect of the cigarette exposure. From the available pool of the original cohort, the present report deals with results obtained on 225 subjects drawn from the following plant locations: coke by-product plant workers (low exposure to coke-oven emissions), coke workers with moderate exposure (jobs performed at the bottom of the oven), coke workers with high exposure (jobs performed at the sides and top of the oven), crane operators and masonry workers. All workers are men. Table 1 summarizes distribution of subjects by location, their mean age, smoking history and average work duration. Top of the oven jobs and crane

TABLE 1
Distribution of steel mill workers by job location and smoking history.

Group	N	Age (mean ± S.D.)	Years worked (mean ± S.D.)
Coke non-smoke	55	35.3 ± 13.2	10.3 ± 8.8
By-products	12	30.6 ± 12.2	8.3 ± 8.1
Low exposure	27	33.4 ± 12.5	7.6 ± 7.0
High exposure	16	42.1 ± 13.2	16.4 ± 9.4
Coke smoke	84	37.6 ± 11.8	10.5 ± 8.6
By-products	20	34.2 ± 11.1	7.6 ± 7.8
Low exposure	27	35.0 ± 13.5	8.3 ± 7.3
High exposure	37	41.4 ± 10.1	13.6 ± 9.1
Non-coke non-smoke	38	35.1 ± 13.6	11.4 ± 10.7
Crane	13	38.7 ± 14.2	12.4 ± 10.8
Mason	25	33.2 ± 13.2	10.8 ± 10.9
Non-coke smoke	48	38.6 ± 13.1	11.4 ± 9.8
Crane	17	45.7 ± 10.4	19.1 ± 8.4
Mason	31	34.6 ± 12.9	7.1 ± 7.8

positions are the most desirable, thus the older ages and long work histories for these men.

Since multiple factors, such as height, age and the number of years in a given job, influence lung function tests all data were analysed statistically by two--way analysis of covariance. Factors of interest were the work area (coke, non--coke), and smoking history (smoker, non-smoker). F tests for smoking status, for example, represent a comparison between a mean pulmonary function value in smokers as compared to the equivalent value for non-smokers, after those values have been adjusted for the effects of all other variables. Statistical analyses were performed through the facilities of the Health Science Computing Facility at the University of California, Los Angeles, by pretested statistical BMD and SPSS programs.

RESULTS

Pulmonary function test (PFT) values collected in 1975 and 1976 are summarized in Table 2. For each group, the mean values shown have been adjusted for any group differences in age, height and work duration. Analysis of covariance on data collected in 1975 showed that two PFT values, VC and $FEV_{1.0}$ were significantly affected by smoking habits ($p < 0.05$). All coke oven workers had lower values for all PFTs when smoking history was held constant but the differences were small and not statistically significant.

Table 2 also lists the mean values for PFTs obtained in 1976 on the same groups of workers. Again, as in 1975, the mean values for all tests of lung volume were lower in the coke oven workers than non-coke workers. The differences in VC were not statistically significant, while the differences for FRC and RV by work site were highly significant ($p < 0.001$). Work site appears to have a variable influence on expiratory flow rate measurements. In these data from 1976 the values significantly affected by smoking included VC, $FEV_{1.0}$ and MMFR, as well as RV and FRC.

Table 3 presents the adjusted values for the changes in PFT which occurred in these subjects between 1975 and 1976. Note that these differences in values are derived by subtracting the values of 1975 from those of 1976 for each individual, and dividing each result by the duration between tests. Smoking status did not seem to influence the changes. Work place, however, appears to play a significant role in these differences in test results between the two years. The average VC values for all workers have dropped, although not significantly. This fall in VC was associated with even larger drops in FRC and RV values, changes which occurred mainly in the coke oven workers. Flow rate indices declined mainly in the non-coke workers.

TABLE 2
Study population, adjusted mean pulmonary function test (PFT) values and significance of factors by smoking history and work place, 1975 and 1976.

Pulmonary function test	Year	Adjusted mean values				F-value		
		Coke non-smoker (N = 55)	Coke smoker (N = 84)	Non-coke non-smoker (N = 38)	Non-coke smoker (N = 48)	Work area	Smoking status	Work area + smoking status
VC	1975	5.04	4.79	5.18	4.87	1.36	7.65*	0.07
(liter)	1976	4.94	4.65	5.08	4.88	3.79	6.15*	0.21
FRC	1975	3.02	3.09	3.04	3.28	1.20	2.16	0.68
(liter)	1976	2.45	2.57	2.73	3.02	14.53**	4.35*	0.78
RV	1975	1.67	1.77	1.88	1.81	1.64	0.02	0.74
(liter)	1976	1.23	1.44	1.55	1.77	21.84**	8.82*	0.00
MMFR	1975	240.77	211.38	243.55	243.43	2.56	1.75	1.78
(liter/minute)	1976	244.87	199.48	213.46	208.52	1.24	5.95*	3.97
$FEV_{1.0}$	1975	3.83	3.56	3.95	3.71	2.59	8.83*	0.03
(liter)	1976	3.78	3.40	3.72	3.59	0.60	9.20*	2.25
$FEV_{1.0}$/VC	1975	75.90	73.89	76.41	75.87	1.54	1.54	0.52
(%)	1976	76.60	72.93	73.13	73.54	1.76	2.19	3.54

*$p < 0.05$;
**$p < 0.001$

TABLE 3
Study population, adjusted mean yearly change in pulmonary function test (PFT) values and significance of factors by smoking history and work place, 1975-1976.

Pulmonary function test	Adjusted mean values				F-value		
	Coke non-smoker (N = 55)	Coke smoker (N = 84)	Non-coke non-smoker (N = 38)	Non-coke smoker (N = 48)	Work area	Smoking status	Work area + smoking status
VC (liter)	−0.108	−0.157	−0.128	−0.010	1.73	0.48	2.90
FRC (liter)	−0.650	−0.570	−0.379	−0.318	8.27*	0.57	0.01
RV (liter)	−0.502	−0.368	−0.343	−0.070	4.41*	3.34	0.40
MMFR (l/min)	5.487	−12.678	−33.940	−32.324	13.69**	1.20	1.14
$FEV_{1.0}$ (liter)	−0.061	−0.167	−0.276	−0.141	4.07*	0.09	6.43*
$FEV_{1.0}/VC$ (%)	0.552	−0.926	−3.850	−2.546	12.73**	0.9	2.67

*$p < 0.05$; **$p < 0.001$

DISCUSSION

There is increasing evidence to indicate that longitudinal studies are invaluable for revealing the risk factors related to the development of chronic disease. For example, the classic monograph on bronchitis and emphysema by Fletcher and co-workers convincingly demonstrated that while cross-sectional studies are useful in generating hypotheses concerning the development of disease, these data are not always substantiated by longitudinal test[3]. Longitudinal studies can uncover subtle evidence of disease not apparent in cross-sectional data. They are less open to biases such at the "survivor effect" which results from the study of a working population of healthier individuals. Similarly, a one time, cross-sectional study of spirometry, in the steel worker population presented here, would not have revealed the changes which became evident after analysis of the longitudinal data. However, it must be noted, that the data reported in the present paper cover only duplicate measurements obtained one year apart. Thus, they can not be considered as conclusive evidence that the changes will continue to occur in consistent fashion as these men age. Nonetheless, this study illustrates the value of repeated measurements.

The 1975 measurements reveal smoking status as the only significant factor which appeared to influence lung function, and its effects were only apparent in two tests, VC and $FEV_{1.0}$. In 1976, the data again demonstrated the influence of smoking, but now work area appeared as a significant factor influencing an increased number of tests. The average VC values were smaller in coke workers (but not significantly so), while the FRC and RV values were definitely lower. These apparent differences were given further support by the annual changes calculated between the two years (Table 3). The pulmonary function test results are affected significantly by work area, for all but VC, with coke oven workers showing the most striking decline in FRC and RV. Flow rates seem to be falling more rapidly in the non-coke worker groups. This is indeed what one would

expect if a fibrosing process were developing in coke workers. Expiratory airway closure would be impeded due to the increased lung elastic recoil, thereby preserving the expiratory flow indices.

This finding of possible restrictive pulmonary dysfunction developing in those coke oven workers, to our knowledge, has never been previously reported. This change may be related to an exposure to silica. Coke oven emissions produced from bituminous coal include silicon which can amount to 2.4% with a range of 0.58 to 6.09% on a weight/weight basis[13]. Therefore, crystalline and/or amorphous silica may be components in such emissions. However, to our knowledge, industrial hygiene quantifications specific to the question have not been performed. The coke oven furnaces at this mill are lined with pure silica, alpha quartz bricks which wear out and must be replaced periodically. This is not to suggest that possible etiological contributions of other components of coke oven emissions can be disregarded.

Silicosis and pneumoconiosis have been well defined among workers in occupations such as mining, sand blasting, stone-masonry and among pottery and foundry workers[11]. Silicosis has also been reported among bricklayers with many years' exposure in rebuilding or repairing oven chambers lined with silica brick[4]. It has also been reported that on clinical examination 50% of coke oven workers were diagnosed as having pneumoconiosis, emphysema, fibrosis and chronic bronchitis[2]. It should be noted that in our survey of the non-coke oven workers in this plant, we have included masonry workers and they showed less restrictive Pulmonary Function Test decrement than did the coke oven workers. We must again caution that the results reported here represent only duplicate tests obtained one year apart and prolonged observations may well reveal different trends.

We recognize that X-ray findings could bolster these pulmonary function test indications of the development of a restrictive problem in coke oven workers. As with many other similar studies our primary focus has not been on X-rays[8,18]. Films are available, but lack the research quality necessary to examine this issue. We hope, in the future to be able to obtain appropriate films and evaluate them in a statistically valid fashion according to the ILO/UICC system.

This report presents preliminary results, which we believe, justify a continued, longitudinal examination of the effects of the work place on workers exposed to coke oven emissions. Lowe and co-workers, in an investigation of "Bronchitis In Two Integrated Steel Works," recognized that pulmonary function tests provide a "sensitive measure of differences between groups of subjects", but they added, local norms must be defined[8]. They found that two populations of men living and working 35 miles apart, employed at very comparable occupations differed significantly both in "physique and in ventilatory capacity." We recognize, as did Lowe, that differences in lung function measurements between groups may be due to totally unrecognized factors. Thus, we hope that our findings of a work place effect on lung function will be examined among coke oven workers in other geographic areas.

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