Lack of combined effects of exposure and smoking on respiratory health in aluminium potroom workers

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Abstract

Objective—To investigate the combined influence on respiratory health of smoking and exposure in an aluminium potroom.

Methods—In a cross sectional study of 75 potroom workers (23 never smokers, 38 current smokers, 14 ex-smokers) and 56 controls in the same plant (watchmen, craftsmen, office workers, laboratory employees; 18 non-smokers, 21 current smokers, 17 ex-smokers), prevalences of respiratory symptoms and spirometric indices were compared.

Results—Smokers in the potroom group had a lower prevalence of respiratory symptoms than never smokers or ex-smokers, which was significant for wheezing (2.6% v 17.4% and 28.6% respectively, both $p < 0.01$), whereas respiratory symptoms in controls tended to be highest in smokers (NS). No effects of potroom work on the prevalence of respiratory symptoms could be detected. In potroom workers, impairment of lung function due to occupational exposure was found only in non-smokers, with lower results for forced vital capacity (FVC) (98.8% predicted), forced expiratory volume in one second (FEV₁) (96.1% predicted) and peak expiratory flow (PEF) (80.2% predicted) compared with controls (114.2, 109.9, and 105.9% predicted; each $p < 0.001$). Conversely, effects of smoking on lung function were only detectable in non-exposed controls (current smokers v non-smokers: FVC 98.8% v 114.2% predicted; $p < 0.01$; FEV₁ 95.5 v 109.9% predicted; $p < 0.05$).

Conclusions—In a cross sectional survey such as this, the effects of both smoking and occupational exposure on respiratory health may be masked in subjects with both risk factors. This is probably due to strong selection processes which result in least susceptible subjects continuing to smoke and working in an atmosphere with respiratory irritants.

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Workers in aluminium potrooms are exposed to various air pollutants—such as dusts (alumina, cryolite, and fluorides), fumes, and gases (mainly hydrogen fluorides and sulphur dioxide). Several studies have shown that working in the potroom may impair lung function^{1–8} whereas others have not.^{9–13} There is some evi-

dence that negative findings could be due to a healthy worker effect.¹⁴

In adults, a dose-dependent effect of smoking on respiratory symptoms¹⁵ and level of lung function^{16–18} is well established. In several cross sectional studies performed in adolescents^{19, 20} only minor effects could be detected for variables such as forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) assuming that never smokers and smokers entered adulthood with the same level of lung function.²¹ Therefore, longitudinal data were required to show that smoking caused a decline in lung function in older²² and younger²³ people. It was speculated that the effects of smoking on lung function of young people, only detectable in longitudinal studies, could be due to an increased susceptibility to the effects of smoking in never smokers²¹ and a higher proportion of “unhealthy subjects” in never smokers¹⁵ than among a group of smokers drawn from the same population. This effect has been labelled the healthy smoker effect.²¹

Given the well established healthy worker effect and the health selection called the healthy smoker effect, the hypothesis of the present study was that subjects occupationally exposed to airway irritants and smoking are the least susceptible subgroup to be affected by smoking and working exposure. Therefore a cross sectional study of respiratory symptoms and spirometry among smoking, ex-smoking, and non-smoking aluminium potroom workers and controls was carried out. The occupational exposure to hydrogen fluoride (HF) and inhalable dust at the potroom under study were below the German threshold limit value at the workplace (HF 2.5 mg/m³, total dust 4 mg/m³).

Subjects and methods

SUBJECTS

The cross sectional survey was carried out in summer 1997 on the plant site of a German prebake aluminium smelter. All smelter employees were invited to participate in the study. Seventy eight workers registered as potroom employees participated in this study (23 never smokers, 38 current smokers, 17 ex-smokers). Never smokers were lifelong non-smokers, ex-smokers were those who stopped smoking for at least 1 year before the study. Therefore three ex-smokers who had stopped smoking during the preceding year were excluded. Fifty seven employees in the office, laboratory, workshop, and gate served as control subjects (18 non-smokers, 22 current smokers, 17 ex-smokers). One pipe smoker was excluded.

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Table 1 Characteristics of the subjects by exposure group and smoking

	Potroom worker						Control					
	Never smoker n=23		Ex-smoker n=14		Current smoker n=38		Never smoker n=18		Ex-smoker n=17		Current smoker n=21	
Females (n)	0		0		0		7*		2		2	
Foreign subjects (n)	16		6		19		1		0		5	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Age (y)	46.7*	9.3	48.5*	7.7	39.7	10.2	47.7*	10.7	45.5	8.8	40.0	8.3
Duration of employment (y)	16.4	7.1	18.2	7.4	13.0	8.9	15.3	8.7	18.3**	5.6	10.3	7.5
Pack-years	0	0	22.5†††	15.8	19.4	10.8	0	0	9.7	9.1	22.0	14.4
Duration of non-smoking (y)			12.2	8.3					15.7	10.4		

* $p < 0.05$; ** $p < 0.01$ v smokers; ††† $p < 0.001$ v the same smoking group of controls; n=total number.

ASSESSMENT OF EFFECTS ON RESPIRATORY HEALTH

Questionnaires

Respiratory symptoms (dyspnoea, wheezing, and cough) during the preceding year, smoking habits, medical and occupational history, personal characteristics, and current duties were recorded in a standardised interview by two physicians. The interview was based on a questionnaire of Kongerud *et al.*²⁴ and most of the questions were translations derived from the British Medical Research Council questionnaire.²⁵

Lung function measurements

Spirometry was performed in all subjects as recommended by the American Thoracic Society.²⁶ Inspiratory vital capacity (IVC), FVC, FEV₁, midexpiratory flow rates (MEF₅₀, MEF₂₅, MEF₂₅₋₇₅), and peak expiratory flow (PEF) were measured with a transportable spirometer (Flowscreen II, Jaeger, Würzburg, Germany). The equipment was volume calibrated before every testing procedure. Lung function tests were performed before the morning shift with the subject in a sitting position with a noseclip. At least three technically satisfactory manoeuvres were measured with the two best acceptable FVC and FEV₁ measurements varying by no more than 10%. Maximum IVC, FVC, FEV₁, and PEF values were used for analysis. Midexpiratory flow rates were taken from the curve with the highest sum of FVC and FEV₁. The measurements were electronically converted to BTPS (body temperature and pressure saturated) conditions.

STATISTICAL ANALYSIS

Standard methods for statistical analyses were used—such as cross tabulation, Fisher's test, *t* test for independent variables, multiple analysis of variance (ANOVA), with final comparison by Newman-Keuls test and multiple regression. All statistical tests were done at $\alpha = 0.05$ significance level.

In this report all references of the lung function are given as percentage of predicted.²⁷

Results

STUDY POPULATION

Table 1 presents the distribution of personal data of potroom and control employees by smoking habit. In both groups, smokers were significantly younger than never smokers. Ex-smoking control employees were employed significantly longer than smokers and had a

Figure 1 Prevalence of respiratory symptoms (* $p < 0.05$, ** $p < 0.01$ v smokers; † $p < 0.05$ v the same control group who smoked).

significantly lower number of pack-years than potroom workers. The control group included significantly more women and fewer foreign subjects.

RESPIRATORY SYMPTOMS

Prevalences of the main respiratory symptoms wheezing, dyspnoea, and cough are given in figure 1. Currently potroom workers who did not smoke had a slightly but not significantly higher prevalence of respiratory symptoms than the control subjects with the same smoking habit. Wheezing was reported by a significantly lower proportion of smokers in the potroom group than in the control group (2.6% v 18.4%; $p < 0.05$).

Among potroom workers, the highest prevalences of respiratory symptoms were found in ex-smokers, whereas among control subjects, smokers complained most often of wheezing, dyspnoea, and cough (NS).

LUNG FUNCTION TESTS

No difference was found between mean lung function results of German and foreign

Figure 2 Mean (SD) spirometry.

employees. Thus, the average results of spirometry for all subjects regardless of nationality are shown in figure 2.

When compared with unexposed workers, only non-smokers in the potroom group had significant lower results for FVC (96.3% *v* 114.2%; $p < 0.001$), FEV₁ (92.3% *v* 109.9%; $p < 0.01$), and PEF (80.2% *v* 105.9%; $p < 0.001$). Conversely, in ex-smokers only FVC was significantly lower (100.4% *v* 109.9%; $p < 0.05$) and in current smokers only the PEF was significantly decreased (80.7% *v* 93.2%; $p < 0.05$).

Among potroom workers, no significant differences could be found between groups of differing smoking habits. Smokers had slightly but not significantly better values of FVC, FEV₁, and MMEF_{25/75} than never smokers. In controls significantly lower results in FVC (98.8% *v* 114.2%; $p < 0.01$) and FEV₁ (95.5% *v* 109.9%; $p < 0.05$) were found in smokers compared with never smokers.

Although in potroom workers the highest spirometric values were found in ex-smokers, in controls the spirometric results were lower in ex-smokers than in never smokers and lowest in smokers.

In a multiple regression model with adjustment for duration of employment, pack-years, and exposure group were shown to be significantly negatively associated with VC and FEV₁ (table 2). Also, the interaction between exposure and number of pack-years was positively correlated with VC and FEV₁ which was significant only for IVC ($p < 0.05$).

Discussion

The present cross sectional study on respiratory health in aluminium potroom workers and controls indicates an adverse health effect of both potroom work and smoking. Our main findings are that (a) the effect of workplace exposure was only detectable in subjects who did not smoke, and (b) the consequence of smoking was only found in non-exposed subjects. Therefore, a combined effect of smoking and occupational exposure was not found.

Due to various air pollutants, work in a potroom is suspected of causing deterioration of respiratory symptoms and reduced lung function in exposed workers even in modern aluminium plants.^{6-8, 28} Other reports, even from the same authors, diverge from these findings.^{12, 14} Particularly in cross sectional studies, it cannot be ruled out that negative findings may be due to a healthy worker effect. Heavy exposure to inhaled irritants may lead to a selection of comparatively resistant people in the workplace whereas more susceptible people have to leave the jobs. There are also some indications for a healthy worker effect in this study. Comparison of the prevalences of respiratory symptoms in potroom workers with those in the general population,²⁹ shows that wheezing occurred significantly less often among potroom workers. Because of the cross sectional design of the study, no exact data were available on workers who left the job due to airway symptoms or disease and other potential factors related to respiratory function. However, it is known that in the years before the study some workers had claimed compensation for suspected occupational airway disease. Also, duration of employment did not show any effect on lung function results.

Comparing the subjects of this study by working categories, a trend towards higher prevalences of respiratory symptoms were found only among non-smokers working in the

Table 2 Multiple regression analysis of VC and FEV₁ as dependent variables and exposure, pack-years, interaction term, and duration of employment as the predictor variables

Dependent variable (% predicted)	Exposure (potroom (+1) <i>v</i> control group (-1))		Pack-years		Interaction term (exposure $\times$ pack-years)		Duration of employment (y)	
	β	SEM of β	β	SE of β	β	SEM of β	β	SEM of β
IVC	-0.39***	0.11	-0.25**	0.08	0.23*	0.11	0.14	0.08
FVC	-0.36**	0.11	-0.24**	0.09	0.20	0.12	0.09	0.31
FEV ₁	-0.28*	0.12	-0.21*	0.09	0.16	0.12	0.10	0.09

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

potroom atmosphere, whereas an effect of the working environment on lung function was clearly found for non-smokers. Thus, it can be speculated that people left their jobs when symptoms occurred.

Studying the effects of smoking, many epidemiological studies described a progressive relative loss of pulmonary function with cumulative smoking. For example, Anderson and Ferris³⁰ found in an early cross sectional study in 1962 a progressive decrease of FEV₁/FVC with increasing pack-years of smoking. Dockery *et al*¹⁸ reported an irreversible loss of FVC and FEV₁ for each pack-year smoked. This finding is consistent with several epidemiological, physiological, and pathological studies of small airways dysfunction which have shown cumulative irreversible effects of smoking.^{31, 32} In this survey these earlier reports were confirmed for control employees by a loss in lung function by smoking habit (highest among smokers, least among never smokers) and the highest prevalence of symptoms among non-exposed smokers.

In exposed smokers, a decrease in lung function compared with non-exposed smokers was only found for PEF ($p < 0.05$). This decline of 13% was relatively small compared with a 26% difference in non-smokers. Apart from this, there is no evidence for impairment of pulmonary function or respiratory symptoms among potroom workers who smoke. Instead, the results indicate fewer symptoms and a trend towards higher spirometric values in the group of smokers compared with never smokers in the potroom group.

Previous surveys have found comparable results in lung function among smokers. In 1990, Becklake and Laloo²¹ summarised 13 cross sectional studies that are compatible with the presence of a healthy smoker effect. A later study of Xu *et al*¹⁵ on the general population confirmed such an effect. Becklake and Laloo²¹ concluded that the experiences of exposure to smoking could be modified more easily than working exposure by not starting, stopping, or by adjusting the exposure dose. This may induce a health selection into the smoking habit called healthy smoker effect. The hypothesis is supported by the absence of effects of smoking on younger people¹⁹ and by a prospective study on 200 teenagers in Los Angeles.³³ In that survey spirometric indices of lung function were shown to be predictors of future smoking. The higher the lung function values of the adolescents were, the higher was the probability that they started to smoke. Due to the voluntary character of smoking, a person may be less likely to take up the smoking habit if it caused discomfort or unpleasant sensations. Thus, it can be assumed that non-smokers and smokers did not enter adulthood with the same level of lung function.

Comparing the results with more recent studies on respiratory health among aluminium potroom workers, there is some evidence for a similar health selection among smokers. Alessandri *et al*⁶ found a significantly higher proportion of subjects with impaired FVC only in potroom employees who did not

smoke compared with controls. In the control group, a significantly higher number of smokers had a decrease in FEV₁ than did people who never smoked. Akbar-Khanzadeh⁹ reported a significantly higher prevalence of shortness of breath among potroom workers who did not smoke than among smokers, whereas in the control group the opposite relation was found. In a longitudinal study, Chan-Yeung *et al*¹⁴ showed a smaller annual decline in young (< 30 years), highly exposed potroom workers who smoked than in ex-smokers or never smokers of the same age group. Although most of the investigations on smoking and respiratory health did not focus on work related exposure, studies on work related impairment of respiratory health often failed to take both healthy smoker and healthy worker effects into account. This could be due to the fact that pulmonary function values are always expected to be decreased by smoking in all cases.

This study indicates that the combined exposure to potroom dust in the work place and private cigarette smoke leads to a selection of workers with comparatively low susceptibility to either of both. Taking into account the healthy worker effect, a higher proportion of unhealthy subjects was found among workers with low exposure than high exposure. Due to the healthy smoker effect, a higher percentage of unhealthy subjects is expected among non-smokers than among smokers. Thus, in highly exposed smokers, only a very low proportion of unhealthy subjects could be detected. This was confirmed in our study by a multiple regression model. The interaction between pack-years and exposure group indicated better lung function results for exposed subjects with a long smoking history. Non-exposed smokers with many pack-years were found to have the lowest spirometric values. This finding has to be confirmed by a study on many cases and controls to increase the statistical power.

In conclusion, there are two different health selection processes among aluminium potroom workers. The magnitude of each effect is difficult to estimate. Ignoring these effects can result in serious underestimation on the ill health consequences of exposures on lung function in cross sectional studies. For example, comparing only the workers who were current smokers of both groups, inverse effects of potroom work on respiratory symptoms were observed. Likewise, a comparison of lung function results with the predicted values showed only a small decrease. Therefore, it is important to take those effects into account when investigating the effects of smoking as well as of occupational exposure by suitable controls or longitudinal studies. Further research is necessary to identify people at risk of being affected by inhaled pollutants including tobacco smoke. Also it would be interesting to determine the level of the lung function before and some years after starting smoking and work in a contaminated environment in a prospective study.

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