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RESPIRATORY DISORDERS IN STAINLESS STEEL WORKERS

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The study involved 106 workers exposed to stainless steel dust (47 stainless steel welders, 59 stainless steel handling workers) and 80 controls. Respiratory impairment was evaluated by means of a standardised questionnaire, clinical examination and lung function tests (spirometry, forced expiratory flow). Dyspnoea was encountered more frequently among exposed workers but there was no greater prevalence of chronic bronchitis compared to the control group. Lung function tests (FEV_1, PEF, FEF_{75}, FEF_{50}, FEF_{25}) were significantly lower in the exposed group. Smoking did not contribute essentially to these changes. The results confirm that stainless steel dust is an important cause of the development of respiratory obstructive disorders in the industrial working population.

Exposure to various air pollutants in modern industry is one of the aetiological factors in the occurrence of pathological changes in respiratory pathways. The metal manufacturing industry, with the presence of numerous particles of metals and various irritant gases, represents considerable occupational risk. Alloy steel is frequently used because of its specific characteristics. One of its most frequently used varieties is chromium-nickel or stainless steel, because of resistance to the effects of acid and oxidation. Fumes which are generated during welding of stainless steel contain significantly more aluminium, magnesium, silicon, titanium, chromium, manganese, nickel and zinc than the fumes of mild steel welding (1 – 3) (Table 1). Because of this difference, exposure to stainless steel welding fumes is considered to be relevant to the development of pathological changes and reactions at the level of the bronchial tree (3 – 5). The presence of gaseous components should not be ignored, of which nitrogen oxides and ozone are particularly important (6).

Opinions concerning welding as a risk of the development of chronic bronchitis and functional ventilatory impairment are controversial. The majority of authors consider that the inhalation of welding fumes creates a predisposition for the development of chronic bronchitis (7 – 14). Investigations of the respiratory functions of welders have

Table 1.

Chemical composition of fumes during welding (Stern and co-workers, reference 1)

Element	Concentration during welding		
	Mild steel % (range)	Stainless steel	
		Soluble in acids %	Soluble in water %
Al	1.56	7.5	6.3
Na	0.92 (0.2 – 1.2)	2.5	1.8
Mg	2.86 (2.5 – 3.3)	14.7	6.3
F	8.89 (6.6 – 11.8)	7.3	–
Si	0.28 (0.09 – 0.56)	22.1	19.5
K	14.31 (10.9 – 19.9)	1.4	0.44
Ca	12.92 (11.7 – 14.7)	2.12	–
Ti	0.809 (0.64 – 1.0)	3.8	3.6
Cr	0.1	2.7	0.25
Mn	3.34 (2.9 – 4.2)	6.3	0.008
Fe	24.34 (16.4 – 29.2)	0.53	0.005
Ni	0.01	0.027	–
Cu	0.29 (0.025 – 0.36)	0.16	0.007
Zn	0.01 (0.05 – 0.25)	0.12	0.07
Mo	0.01	–	–
Ag	0.005	–	–
Cd	0.005	–	–
Pb	0.005	–	–

produced different results, ranging from the absence of pathological changes (7, 11, 13, 15) to the development of restrictive (8, 12, 15, 16) and obstructive (3, 7, 9, 17 – 19) ventilatory changes. However, all those data relate to welders of mild steel or other metals, while papers on respiratory disorders and functions pertaining to welders of stainless steel are rare (3, 5, 14). This investigation aimed at establishing a relationship between exposure to the dust and fumes of stainless steel welding and the development of chronic bronchitis and pathological changes in lung functions.

SUBJECTS AND METHODS

A group of 106 workers, exposed to stainless steel at work, were examined. The group included 47 electric arc welders and 59 workers employed in process of turning and stainless steel polishing. The investigation included a control group of 80 workers employed in various jobs, during which they were not exposed to irritant or allergogenic pollutants in the work atmosphere. The control group matched the exposed group by age, sex, height, smoking habits, place of residence and social status.

Exposed subjects were aged 22–61 years (38.5 ± 10.5) and the controls 19–59 years (36.9 ± 10.2). The smoker to non-smoker ratio and classification of smokers according to *Brinkman and Coates* (20) into light, moderate and heavy smokers, were identical for both groups. The mean duration of exposure to stainless steel dust was up to 14 years, ranging from four to 34 years. Data on cough, expectoration, dyspnoea, choking and smoking habits were obtained by a questionnaire on respiratory symptoms of the *Committee for Chronic Bronchitis of the Medical Research Council* (21). Chronic bronchitis was therefore defined according to the criteria of the above Committee, and dyspnoea was defined as dyspnoea while walking without any particular effort (21). Ventilatry functions for all subjects were measured on a »Pneumoscreen«, Jaeger, apparatus: forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1) and parameters of the flow-volume curve, peak expiratory flow (PEF), forced expiratory flow at 75% FVC (FEF_{75}), at 50% FVC (FEF_{50}) and at 25% FVC (FEF_{25}). Examination was conducted on three occasions, at the workplace, at the end of the work week, and the optimal result was taken as the test result. Reference values were determined according to *Cherniack and Raber* (22) and *Cherniack* (23) and Tiffeneau index was also calculated. A chest radiograph of the welders excluded pneumoconiosis and other lung diseases which could have influenced ventilatory capacity. The results of the measurements of ventilatory parameters were analysed by t-test and statistical significance was calculated at the levels of 0.05 and 0.01.

RESULTS

The frequency of symptoms of chronic bronchitis was identical in the exposed and control groups, including analysis by category of smokers. A higher frequency of symptoms of chronic bronchitis was seen in exposed heavy smokers as compared to

Table 2.

Frequency of chronic bronchitis in exposed and control subjects by smoking category

Smoking category	Exposed group			Control group				
	n	n*	%	n	n*	%	t	P
Smokers								
light	29	8	27.6	25	3	12.0	1.48	n.s.
moderate	33	18	54.5	24	16	66.7	0.94	n.s.
heavy	9	6	66.7	6	1	16.0	–	–
Non-smokers	35	8	22.8	25	5	20.0	0.26	n.s.
Total	106	40	37.7	80	25	31.3	0.92	n.s.

n – number of subjects; n* – subjects with chronic bronchitis

Table 3.

Respiratory functions in stainless steel workers

Respiratory functions	Total Exposed n=106		Total Control n=80		Smokers Exposed n=71	Smokers Control n=55	Non-smokers Exposed n=35	Non-smokers Control n=25
FVC	4.49±0.96	(99.1)	4.71±0.83	(98.5)	4.48±0.87	4.69±0.87	4.50±0.90	4.75±0.89
FEV_1	3.58±0.88**	(93.2)*	4.10±0.68	(97.6)	3.55±0.79**	3.96±0.68	3.62±0.89**	4.41±0.69
PEF	7.93±2.24**	(87.8)**	9.22±1.44	(97.7)	7.80±2.07*	8.46±1.47	8.13±2.20**	10.89±1.45
FEF_{25}	2.06±0.77**	(73.6)**	2.95±0.64	(96.7)	1.93±0.74**	2.93±0.66	2.26±0.75**	2.99±0.60
FEF_{50}	4.94±1.49**	(88.2)**	5.80±1.03	(98.4)	4.90±1.51**	5.82±1.10	5.00±1.40**	5.76±1.01
FEF_{75}	7.02±1.99**	(91.2)	7.64±1.33	(95.9)	7.07±1.94*	7.47±1.40	6.94±1.97	7.42±1.21
FEV_1/FVC%		79.7*		87.0	79.2*	84.4	80.4**	92.8

Results are $\bar{X} \pm SD$ (% of the predicted values)

* <P 0.05

** <P 0.01

heavy smokers in the control group. However, the difference was not tested because of the insufficient number of chronic bronchitics in the control group (Table 2). Workers complaining of dyspnoea and choking were significantly more numerous among the exposed (43%) than among the controls (13.8%) ($P < 0.01$). Exposed subjects had significantly lower values of the ventilatory parameters examined with the exception of FVC (Table 3). The same was true of a subgroup of welders and a subgroup of workers employed in stainless steel manufacture. Comparing the results of measurement of ventilatory function in smokers and non-smokers in individual groups, no significant difference was found apart from that for FVC in smokers and for FVC and FEF_{75} in exposed non-smokers as related to the controls (Table 3). Comparison of the mean values of the spirometric parameters, expressed as percentages of predicted values pointed to a significant decrease in FEV_1, PEF, FEF_{25}, FEF_{50} and in Tiffeneau index in exposed subjects in relation to the control (Table 3). There was no correlation between the time of exposure to stainless steel dust and findings of pathological ventilatory functions.

DISCUSSION

This investigation did not demonstrate a difference in the frequency of symptoms of chronic bronchitis between workers exposed to stainless steel dust and control workers. The occurrence of symptoms of chronic bronchitis could be linked to the smoking habit in heavy smokers only, although a statistical connection could not be established because of the small number of subjects in this subgroup. According to *Kalliomäki* (5), who examined the respiratory symptoms of stainless steel and mild steel welders, the frequency of symptoms of chronic bronchitis did not depend on pollution of the air in the work environment. *Sjögren* (14) came to the same conclusion. Earlier reports (5) on the frequent occurrence of dyspnoea and choking in stainless steel workers were also confirmed.

Comparative evaluation of respiratory functional tests in exposed and control subjects pointed to a significant decrease in FEV_1, PEF, FEF_{25}, FEF_{50} ($P < 0.01$) and FEF_{75} and Tiffeneau index ($P < 0.05$) in the former group. No change was seen for FVC. Analysis by subgroups offered similar results. In spite of the fact that stainless steel welders were exposed to biologically more active fumes (1–3) (in addition to many metals, nitrogen oxide, ozone, carbon dioxide, carbon monoxide, fluorides, silicon dioxide were also present) than workers in stainless steel manufacture, both groups showed identical changes in respiratory parameters. This might have been due to a selection among welders, because the subjects who were particularly susceptible to a noxious influence of welding fumes tended to quit welding (14). Considering the known respiratory effect of smoking the measured respiratory parametes were comparatively analysed for exposed and non-exposed smokers showing significantly lower values in the exposed group. Equal results were obtained when the lung functions measured in exposed non-smokers were compared to those of non-smoking controls. This indicates that smoking had no effect on the differences found. The results of other investigations also indicate a detrimental effect of stainless steel welding fumes on lung function. Thus *Kalliomäki* (5) reported a significant fall in FEF_{25} and FEF_{50} in stainless steel welders in relation to predicted values, without a statistically significant effect of smoking on these parameters. *Keskinen* (3) used bronchoprovocation tests with stainless steel welding fumes to provoke a significant fall in PEF values in welders with respiratory disorders, indicating the possibility of the development of bronchial asthma caused by stainless steel welding fumes, i.e. chromium as its relevant constituent. In accordance with the results of other authors (3, 5, 24, 25) this investigation established a significant decrease in ventilatory parameters characteristic of broncho-obstruction in workers exposed to stainless steel dust in relation to a control group.

CONCLUSION

Comparison of the results of the ventilatory function tests in workers exposed to stainless steel dust and in control workers showed a statistically significant decrease in FEV_1, Tiffeneau index and parameters of flow-volume curve, both in smokers and non-smokers. This could be attributed to the effect of pollution of the workplace. It is concluded that the dust created during the manufacture and welding of stainless steel is a contributing agent in the development of obstructive respiratory disorders in the industrial working population.

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Sažetak

RESPIRATORNE SMETNJE RADNIKA IZLOŽENIH NERĐAJUĆEM ČELIKU

Pregledano je 106 radnika izloženih prašini nerđajućeg čelika, i to 47 zavarivača i 59 radnika zaposlenih na obradi nerđajućeg čelika, te 80 radnika kontrolne skupine koji nisu bili izloženi djelovanju bilo kojeg iritativnog ili alergogenog aerosola. Upotrebom upitnika o respiratornim smetnjama Komiteta za kronični bronhitis nije utvrđena veća učestalost kroničnog bronhitisa, ali je otežano disanje i gušenje bilo češće u radnika eksponirane skupine u odnosu na kontrolnu. Provjerom funkcionalnih testova ventilacije (FVK, FEV_1, PEF, FEF_{75}, FEF_{50}, FEF_{25}) ustanovljeno je kod eksponirane skupine značajno sniženje svih parametara osim FVK. Pušenje nije bitno utjecalo na nađene promjene. Ovi rezultati potvrđuju da je prašina nerđajućeg čelika jedan od činilaca razvoja opstruktivnih dišnih smetnji kod industrijske populacije.

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