

Respiratory status of stainless steel and mild steel welders

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KALLIOMÄKI P-L, KALLIOMÄKI K, KORHONEN O, NORDMAN H, RAHKONEN E, VAARANEN V. Respiratory status of stainless steel and mild steel welders. *Scand j work environ health* 8 (1982): suppl 1, 117-121. Eighty-three full-time stainless steel and 29 mild steel welders from one shipyard were examined clinically, and their lung function was measured. The stainless steel welders had used both tungsten inert-gas (low-fume concentration) and manual metal-arc (MMA) (high-fume concentration) welding methods. The individual exposure of the welders was estimated based on the time spent doing MMA welding, the amount of retained contaminants in the lungs (magneto-pulmography), and urinary chromium excretion. The results suggest that there is a greater prevalence of small airway disease among shipyard mild steel MMA welders than among stainless steel welders. Among the stainless steel welders the impairment of lung function parameters was associated with the MMA welding method. The type of welding, then, is important when the health hazards of welders are studied, and welders cannot be regarded as a single, homogeneous group.

Key terms: respiratory disorders, shipyard welders.

The welding process and the properties of welding fumes depend on the material to be welded and on the welding method. Therefore welders using different welding methods, such as manual metal-arc (MMA) and shield gas [tungsten inert-gas (TIG) & metal inert-gas (MIG)], must be considered separately. Numerous epidemiologic studies of the respiratory condition of mild steel MMA welders have been done (6), but very few investigations have dealt with the effects of these fumes on the health of stainless steel welders (8).

This paper presents the prevalence of respiratory symptoms and lung function among 83 stainless steel welders who have used both TIG and MMA welding techniques. The fume emission of the MMA

process is about 100 times more intensive than that of the TIG process (4). Thus welders using only the TIG method, and only on stainless steel, can be used as referents when the effects of welding fumes are considered.

Subjects

Stainless steel welders

Eighty-three full-time stainless steel welders were examined. Their mean age was 39 a (SD 10), and the mean length of their welding exposure 15 a (SD 8). They had also welded mild steel using the MMA method 11 % of their worktime during the last 10 a.

One selection criterion was a minimal exposure to other industrial metal aerosols such as mild steel welding fumes. The length of time spent on stainless steel welding had to be at least 5 a.

The welders were divided into four

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groups according to the percentage of time spent doing MMA welding during the last 10 a (table 1).

Their mean age was 44 a (SD 11), and the mean length to exposure to mild steel MMA welding fumes 20 a (SD 7) (table 1).

Mild steel manual metal-arc welders

Twenty-nine mild steel MMA welders from one shipyard were also examined.

Methods

The examinations included a detailed oc-

Table 1. Age and years of exposure of stainless and mild steel welders classified according to the main welding technique. The average time spent on manual metal-arc (MMA) welding is given in percentages. (TIG = tungsten inert-gas)

Group	N	Age (a)		Exposure (a)		MMA (%)	Exposure parameters (Mean $\pm$ SD)	
		Mean	SD	Mean	SD		Amount of lung dust (g)	Urinary chromium concentration ^a (μ g/l)
Stainless steel welders	83	39	10	14	8	52		
TIG (≤ 10 % MMA)	20	38	9	13	9	3	0.2 $\pm$ 0.3	5 $\pm$ 2
Nonsmokers	13	40		14				
Smokers	7	33		11				
"Mixed" ₁ (11—40 % MMA)	16	38	10	10	5	30	1.2 $\pm$ 1.3	13 $\pm$ 10
Nonsmokers	9	39		11				
Smokers	7	37		8				
"Mixed" ₂ (50—89 % MMA)	18	34	11	11	5	58	1.9 $\pm$ 2.0	14 $\pm$ 11
Nonsmokers	14	33		11				
Smokers	4	34		13				
MMA (≥ 80 % MMA)	29	42	10	19	10	96	4.0 $\pm$ 2.7	32 $\pm$ 42
Nonsmokers	14	43		20				
Smokers	15	41		18				
Mild steel welders	29	44	7	20	7	100	1.0	
Nonsmokers	19	45		20				
Smokers	10	43		20				

^a Urinary chromium concentration of 1 μ g/l = 0.07 μ mol/l.

Table 2. Respiratory and subjective symptoms associated with the welding of stainless steel and the effects of the welding method (expressed as % of manual metal-arc welding, see table 1), exposure time, and smoking on the symptoms.

Symptoms	Mean (%)	Estimated effect of welding method ^a (%)	Estimated effect of welding exposure ^b (%)	Effect of smoking (%)
Respiratory symptoms				
Cough	11	+10	+11	+15 *
Phlegm	29	+24	+ 8	+16
Dyspnea, grade II-IV	10	+17 *	+17 *	+14
Chronic rhinitis	40	+15	+17	+22 *
Subjective symptoms associated with welding				
Irritation in the upper respiratory tract	66	+25	+ 5	+ 2
Attacks of dyspnea associated with welding	26	+ 0	+32	—13

^a Obtained from the regression equations by multiplying the slope by 100 %.

^b Obtained from the regression equations by multiplying the slope by the average exposure time of 14 a.

* $p < 0.05$.

cupational history, the Medical Research Council's questionnaire on chronic bronchitis (5), and a detailed questionnaire on subjective respiratory symptoms associated with welding. Dust retained in the lung was estimated by a magnetic measuring method (2), and urinary chromium excretion was also determined for the stainless steel welders (7).

The lung function tests included spirometry, maximal expiratory flow (MEF) volume curves [MEF at 50 % (MEF₅₀) and 25 % (MEF₂₅) of the forced vital capacity], closing volume, and carbon monoxide transfer factor (diffusing capacity).

Statistical methods

The statistical comparisons of the lung function values were based on the Student's *t*-test and those of the respiratory symptoms on the chi-square test. The estimated effects of exposure time and welding method (MMA %) were calculated from the regression coefficients. The significance of the coefficients was checked with Student's *t*-test.

Results and comments

Findings among stainless steel welders

The prevalence of chronic respiratory symptoms and acute subjective symptoms associated with welding among stainless

steel welders are presented in table 2. The prevalence of symptoms of chronic bronchitis was dependent only on smoking. An increased frequency of dyspnea (grade II–IV) was found among the MMA welders. The most prevalent symptom was chronic rhinitis (40 %), and it tended to be associated with stainless steel MMA welding-fume exposure.

Stainless steel MMA welders tended to experience more irritation in the upper respiratory tract in association with welding than the stainless steel TIG welders. Some of the workers in all the groups complained of occasional attacks of dyspnea during welding (table 2). For four stainless steel MMA welders the findings suggested a possibility of occupational asthma (3).

The effects of exposure time, of the MMA welding method, and of smoking upon the results of the lung function parameters are presented in table 3. The mean vital capacity (VC) of all the groups was within the normal limits, but it decreased faster than predicted (1) as a function of exposure time (48 ml/a vs 22 ml/a). This occurrence was not dependent on the welding method. Significant deterioration was observed in values for the forced expiratory volume in 1 s (FEV_{1.0}).

Stainless steel MMA welding-fume exposure mostly affected the flow volume curves, irrespective of exposure time (table 3). Smoking also tended to affect these

See 1

Table 3. Lung functions of stainless steel welders and effects of exposure time, welding method [% of manual metal-arch (MMA) welding] and smoking on the lung function values. (VC = vital capacity, FEV_{1.0} = forced expiratory volume in 1 s, MEF₅₀ = maximum expiratory flow of 50 % of the forced VC, MEF₂₅ = maximum expiratory flow at 25 % of the forced VC, T_{LCO} = carbon monoxide transfer factor)

Lung function (% of reference value)	Mean (%)	SD (%)	Estimated effect of welding exposure ^a (%)	Estimated effect of MMA-welding method ^b (%)	Effect of smoking (%)
VC	102	14	— 8 **	— 2	0
FEV _{1.0}	105	16	— 2	— 2	— 3
MEF ₅₀	93	28	— 1	— 17 *	— 5
MEF ₂₅	101	40	+ 7	— 37 **	— 16
Closing volume difference	+ 4.2 **	7.0	+ 0.8	+ 2.6 *	+ 3.7 *
T _{LCO}	102	16	— 2	— 6	— 12 **

^a Obtained from the regression equations by multiplying the slope by the average exposure time of 14 a.

^b Obtained from the regression equations by multiplying the slope by 100 %.

* *p* < 0.05, ** *p* < 0.01.

parameters, but not significantly. The difference in the closing volume values was primarily dependent on smoking, but stainless steel MMA welding exposure also affected this parameter. The carbon monoxide transfer factor (T_{LCO}) values were only affected by smoking.

Comparison of findings among stainless steel and mild steel manual metal-arc welders

No difference was observed in the prevalence of cough, phlegm, and dyspnea (grade II—IV) between stainless and mild

steel MMA welders (tables 2 & 4). Smoking had similar effects on both groups. Chronic rhinitis seemed to be associated with stainless steel MMA welding exposure. No statistically significant difference in subjective symptoms associated with welding was observed. A proportion of the stainless steel MMA welders (24 %) complained of occasional reversible attacks of dyspnea associated with welding, especially after long periods in an enclosed space. These attacks of dyspnea were not however similar to the asthmatic reactions reported by the four MMA welders.

Table 5 presents the mean values of the lung functions, the deviations from the

Table 4. Respiratory symptoms among mild steel, manual metal-arc welders and the effects of exposure time and smoking on symptoms.

Symptoms	Mean (%)	Effect of 20-a exposure ^a (%)	Effect of smoking (%)
Respiratory symptoms			
Cough	17	0	+ 19
Phlegm	31	+ 29	+ 19
Dyspnea, grade II—IV	24	+ 50 **	+ 14
Chronic rhinitis	28	+ 7	+ 19
Subjective symptoms associated with welding			
Irritation in the upper respiratory tract	74	— 14	+ 24
Attack of dyspnea associated with welding	24	+ 14	+ 31

^a Prevalence among "old" welders minus that among "young" welders.

** $p < 0.01$.

Table 5. Comparison of lung function tests and effects of welding exposure and smoking on lung function values of mild steel (MS) and stainless steel (SS) manual metal-arc welders. (VC = vital capacity, $FEV_{1.0}$ = forced expiratory volume in 1 s, MEF_{50} = maximum expiratory flow at 50 % of the forced VC, MEF_{25} = maximum expiratory flow at 25 % of the forced VC, T_{LCO} = carbon monoxide transfer factor)

Lung function (% of reference value)	Mean values		Deviation from reference values (%)		Estimated effect of welding exposure ^a (%)		Effect of smoking (%)	
	MS	SS	MS	SS	MS	SS	MS	SS
VC	94	100	— 6 **	0	— 12 *	— 7	— 6	0
$FEV_{1.0}$	100	105	0	5	— 13	— 1	— 6	— 3
MEF_{50}	84	92	— 16 **	— 8	— 22	— 5	3	— 5
MEF_{25}	79	98	— 21 ***	— 2	— 31 *	— 3	— 9	— 16
Closing volume (CV) difference ($CV_{observed} - CV_{predicted}$)	1.4	4.2	1.4 *	4.2 **	1.2	0.0	3.2 *	3.7 *
T_{LCO}	90	98	— 10 ***	— 2	— 15 *	3	— 3	— 12 *

^a Average exposure time multiplied by the slope of the corresponding regression equation.

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

reference values, and the effects of the length of exposure time and of smoking upon the functions of the mild and stainless steel MMA welders.

Generally, the mild steel MMA welders' lung functions were impaired the most. Lung function values changed differently among mild and stainless steel MMA welders.

The VC decreased faster than predicted as a function of exposure time, especially in the mild steel MMA welders. Smoking had only a slight effect on the VC values of the mild steel MMA welders.

The FEV_{1.0} values decreased slightly among the stainless steel MMA welders only. The flow volume curves (MEF₂₅, MEF₅₀) seemed to be associated with MMA welding-fume exposure. These parameters decreased the most significantly in the mild steel MMA welders, and there was a significant correlation between MEF₂₅ and exposure time. The impairment of these parameters for the stainless steel welders was different; it was associated only with the MMA welding method (table 3). Smoking had only a slight effect on the flow volume curves of mild steel MMA welders.

The T_{LC0} of the mild steel MMA welders was significantly ($p < 0.001$) decreased, and the effect of smoking was very slight. Among the stainless steel MMA welders T_{LC0} was affected only by smoking.

Conclusions

1. Welders cannot be considered a homogeneous group in respect to exposure and the possible associated health hazards.
2. Changes in the lung function parameters of mild and stainless steel welders seem to differ. Generally speaking, the lung functions of mild steel MMA shipyard welders are the most impaired.
3. According to our preliminary study lung function tests indicate that pathological changes mainly occur in the peripheral airways and alveoli. All welding processes produce various toxic

gases and completely respirable fume particles. The pollutants mainly accumulate in the lower parts of the respiratory organs.

4. It is now recognized that conventional spirometric indices [such as VC, FEV_{1.0} and FEV % (percentage of FEV_{1.0} to forced vital capacity)] are not sensitive enough to detect changes in small peripheral airways. It might therefore be that the results of previous spirometric studies that compared welders and referents conflicted because of the insensitivity of the method used.

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