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Pulmonary Effects of Occupational Exposure to Welding Fumes

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Abstract: This article presents the results of a cross-sectional study in a randomly selected factory performing welding operation in Iran to determine the respiratory symptoms, pulmonary function and x-ray changes in the employees. Through this study, the data obtained from 160 mild steel (MS) welders and 86 healthy volunteers were statically analyzed. Two groups of workers were matched according to their age, height, smoking habit and years of service. Their health survey was evaluated by questionnaire, spirometry, chest x-ray and clinical evaluation. In addition, welding fumes were determined by Atomic absorption and X-ray fluorescence method. Concentrations of personal breathing zone and Arc welding fumes were 7.13 mg/m^3 and 17.49 mg/m^3, respectively, that showed high concentration compared to the Threshold Limit Value-Time Weighted Average (TLV-TWA). After adjustment for tobacco habits, the welders presented a higher prevalence of bronchial irrelative symptoms such as cough, phlegm, dyspnea, and wheezing than the controls (p=0.05). These results indicate that smoking potentates the effect of welding fumes on chronic bronchitis. The ventilatory functions (VC, FVC, FEV_1, and MMEF) were significantly lower in the welders compared with controls (P=0.05). Lung functions in non-smoking welders were impaired and a significant tobacco effect was not found. Also Chest X-ray abnormalities were higher in welders (13.8%) than the control group (2.5%). The results of multiple regression indicated that age and height were not a confounding factor. Occupational health program to reduce the total fumes exposure, and periodical medical examination are measures to prevent lung disease.

Key words: Welding fumes, Respiratory symptoms, Pulmonary function, Occupational exposure, Iran

INTRODUCTION

Welding is a process for joining metals in which coalescence is produced by heating the metal to a suitable temperature (Burgess, W.A., 1981). The potential hazards from exposure to metal fume during common welding techniques obviously depend on the metal being welded and the composition of the welding electrode[1]. Welding activities such as position of the welders, welding processes, increasing electrode diameter, and large shop with general ventilation may involve atmospheric exposure to a number of fume components [1, 2].Each welding technique and application produces a characteristic composition of fumes and gases with metallic and non-metallic components (Burgess, W.A., 1981;Akbarkhanzadeh, F., 1979). Thus, if mild steel is welded, fumes in Manual Metal Arc welding (MMA) consist of Fe, Mn, Si, Na, Ca, F (Burgess, W.A., 1981;Akbarkhanzadeh, F., 1979). Pollutants such as toxic gases and fume particles produced in the welding process and tobacco smoke can gain access to the respiratory tract (Peter, J. Hewitt, 2001;Antonini, J.M., 2003). Some of these particles are able to reach the terminal alveolar ending. They may be destroyed, distributed throughout the body, or remain in the lung and lymph channels and glands within the chest which drain the lung area, where they may exert a wide variety of effects (Mur, J., D. Teculescn, 1985;James, M., S. Sam, 2007). Welding is often associated with respiratory symptoms and functional disturbances, i.e., inability to inspire deeply, inability to exhale (airway obstruction). Welders more often have chronic bronchitis and respiratory impairment (Cotes, J.E., E.L. Feinman, 1989;Kilburn, K.H., R.H. Warshaw, 1998). The possible harmful effects of welding fumes

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have been discussed for many years, especially with increasing use of Manual Metal Arc (MMA), and Metal Inert Gas (MIG), which usually involves various potential respiratory illnesses (James, M., S. Sam, 2007;Cotes, J.E., E.L. Feinman, 1989;Kilburn, K.H., R.H. Warshaw, 1998). Most studies showed respiratory symptoms such as cough, phlegm, dyspnea, and wheezing to be greater in welders than in comparable control groups (Kilburn, K.H., R.H. Warshaw, 1998;Akbarkhanzadeh, F., 1980). Studies by Kilburn *et al.* (1998) and Akbarkhanzadeh, 1980, showed relationships between exposure to welding fumes and the development of respiratory symptoms. Moreover, the great majority of studies have been performed in European countries (Peter, J. Hewitt, 2001;ATS Statement, 1987), United States (Antonini, J.M., 2003;Mur, J., D. Teculescn, 1985;International Labour Office Guidelines, 1980) and Netherlands (Van der wall, J.J., 1990) in plants with proper or relative exposure control methods. Because of the lack of statistical data, the extent of harm and discomfort to workers and damage to the environment in developing countries is not clear, despite the fact that there are many welding operations in the plants. The objective of this cross-sectional study was to assess the influence of MS welding activity and the duration of the welding activity on the respiratory health and the chronic pulmonary effects in a big production factory in Arak, the capital city of the central province of Iran and the relations of these to the level of welding fumes in the work environment.

MATERIALS AND METHODS

Study Samples:

The study was conducted in a big production plant located in Arak, the capital city of central province of Iran. In this plant, MMA and MIG welding techniques were used with covered electrodes for mild steel. The welding operations were performed manually and no means of emission control was provided for control the total of fume in the processes. This study was constructed to investigate the environmental welding fumes released in the welding processes as well as their effectiveness on welder's respiratory system. In this study, 160 welders with occupational exposure and 86 official and maintenance shop personnel's who were all healthy adults were considered as control group. Two groups were matched according to their age, height, smoking habit and years of service. The inclusion and exclusion criteria of welders were based on:

The inclusion criteria:

- The duration of welding activity, with at least five years of continuous welding.
- The welding metal: only mild steel was considered at should be welded at the time of the study.
- The welding processes were, in priority, Manual Metal Arc (MMA) and Metal Inert Gas (MIG).
- The exclusion criteria.
- Occupational history of less than five years.
- Past or present exposure to harmful respiratory substances, especially silica, asbestos, or solvents.

One hundred and sixty MS welders recruited for the study were divided into two principal groups according to the welding technique: The MMA (124 persons), and the MIG (36 persons). The average age of MS welders was 36.48 years (standard deviation [SD], 7.95). The average weight and height were, respectively, 68 Kg (SD, 8.87) and 170.1 CM (SD, 8.68). The time in the workplace was 12.2 years (SD, 6.15). With regard to smoking habits, MS welders were distributed as follows: 36: current smokers (C-S), and 64% non-smokers (N-S). The controls worked more of 10 years in the office, and maintenance shop, with no welding exposure. All the control subjects, working in the vicinity of welding areas or at polluted workplaces were excluded. They had no current or previous welding exposure, and past or current exposure to silica, asbestos, or solvents. The average age of controls was 32.26 years (SD, 7.65). The average weight and height were, respectively, 68.3 Kg (SD, 7.76) and 170.7 CM (SD, 7.29). The average time in the job was 11.6 years (SD, 5.84). With regard to smoking habits, controls were distributed as follows; 38.6% were current smokers and 61.4% were non-smokers. Pack-years smoked were calculated for both welders and controls. A pack-year was defined as having smoked 20 cigarettes a day for 1 year. There was no significant difference between MS welders and controls ($p<0.05$).

Questionnaires:

In this study, the modified British Medical Research council's questionnaire on respiratory symptoms (MRC) (BOHSC., 1998) with additional questions relevant to the objectives of the study was used. The questionnaire on respiratory symptoms was validated and translated in to Persian. The occupational physician was briefed on the contents of the questionnaire, the instructions and on how to ask the questions and what pitfalls to look for. The respiratory symptoms questionnaire was used in an interview to obtain the medical and occupational history and information on smoking habits.

Spirometry:

Pulmonary function were evaluated by spirometric testing (Model PFII, vitalograph Ltd, Buckingham, UK), before and after working shift. The spiromter was volume calibrated by a wet spirometer before starting of the survey and after fortnight. The lung function test was included measurement of vital capacity (VC), forced vital capacity (FVC), forced expiratory volume on second (FEV_1), and maximal midexpiratory flow (MMEF or $FEF_{25\%-75\%}$). Tests were conducted according to American Thoracic Society recommendations (ATS) (ATS Statement, 1987). The procedure for the ventilatory function test was explained individually to the subjects, who were then given a practice test, which was taken while standing. The ventilatory function parameters were measured five times, and an average of three best results was calculated and connected to the body temperature and pressure saturated with water vapor.

Chest X-ray:

Chest x-ray (chest films) were performed and read in according with ILO-80 guidelines (International Labour Office Guidelines, 1980). The expert readers was one academic radiologist.

Welding Fumes Sampling and Analysis:

In the welding processes, the personal and area samples were collected to determine the exposure to welding fumes. Personal samples were collected from the welder's breathing zone and this is defined as approximately 20-30 cm from the nose and mouth. Area samples also were collected in the fixed locations at welders' work stations (Arc welding) in the welding operation. Welding fumes samples were collected using a 0.8 microns pore size and 37 mm diameter mixed cellulose ester (MCE) filter attached to the 37 mm open face cassette at flow rate 2.01, L/ min (MSA. Model (26-2867) and SKC. Model (224-PCX R3). For welding fumes analysis the NIOSH methods, No 7300 and 7301 were used.

Statistical Analysis:

A database file was created in a personal computer and statistical analysis was done by means of the statistical package for social sciences (SPSS). Comparisons of quantitative data were made with analysis of variance (general linear model) and student t-tests wre applied. To study the effects of tobacco, Cochrane analysis was used. Multiple stepwise regressions was also performed. The t-test was too used for testing the influence of smoking on the qualitative values.

RESULTS AND DISCUSSION

Total Fumes:

The results of 320 samples of total welding fumes are presented in Table 1. The duration of personal sampling for welding fumes ranged from 35 to 364 min. The concentrations in 320 (100%) of the total samples exceeded the recommended threshold limit value (TLV) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) for welding total fumes, which is $5 mg/m^3$.

Table 1: Concentration of total fume (mg/m^3) in different places of sampling

Place of sampling	No. of MMA	Samples MIG	Welding MMA	Fumes mg/m^3 MIG	No.(%) of above ACGIH	Samples the limit*
Breathing Zone	124	36	7.9	6.37	160	(100)
Arc welding	124	36	19.45	15.54	160	(100)
Total	248	72	-	-	320	(100)

* $5 mg/m^3$

Respiratory Symptoms and Ventilator of Function Test:

The prevalence of respiratory symptoms and chronic bronchitis is summarized in table 2. The welders showed increased frequency of respiratory symptoms than the control subjects. The differences were significant for cough, phlegm, dyspnea, and wheezing. Since cigarette smoking is a confounder for respiratory symptoms, in this study we classified the subjects with respect to smoking status, and the same analysis was performed: In each group (smokers, non-smokers), symptoms are more frequent among MS welders than among controls. After adjustment on smoking habits, the exposure effect is confirmed for the four respiratory symptoms. The mean ventilator of function measurements have been presented in Table 3. Welders had statistically significant reductions in VC, FVC, and FEV_1 but the means for MMEF was not significantly different. The mean duration of exposure in welders was 12.2±6.15 years (mean ±SD) range, 1- 26 years. The t-test analysis showed a significant tobacco effect without exposure to fume (table 4).

The current smokers had the lowest lung function capacities. The mean lung function parameters in both smoking and non-smoking groups of welders were less than those of the corresponding groups of controls. The radiography results indicated that the percentage of abnormal x-ray patterns was higher among welders (13.8%) than controls (2.5%). Meanwhile, the results obtained from the χ^2 test showed that respiratory symptoms such as cough (986%),phlegm (85%), dyspnea (90%),and wheezing (81%) correlated with abnormal radiography (p=0.05).

Table 5 summarizes the results obtained for multiple regression equation, between each lung function values for subjects and the explanatory variables such as age and height. The result showed that, all pulmonary variables (VC, FVC, FEV_1, and MMEF) have a positive correlation with age and height (P=0.001).

Table 2: Respiratory symptoms according to exposure

Symptoms	Welders N= 160		Controls N=80		P value
	n	(%)	n	(%)	
Cough during the day	67	42	11	13	P<0.05
Phlegm during the day	73	46	16	19	P<0.05
Dyspnea	59	37	8	8	P<0.05
Wheezing	29	18	4	4.5	P<0.05

Table 3: Ventilatory function according to exposure

Parameter	Welders N= 160		Controls N=86		P value
	mean	(SD)	mean	(SD)	
VC	4.65	0.65	4.88	0.95	p<0.02
FVC	4.73	0.71	4.95	0.90	p<0.04
FEV_1	3.70	0.74	4.40	0.87	p<0.001
MMEF	3.54	1.18	3.70	1.02	p<0.15

Table 4: Ventilatory parameters among welders and controls according to smoking status

Factor	Welders		Controls		t-test	
	C-S N=58 m(SD)	N-S N=102 m(SD)	C-S N=31 m(SD)	N-S N=49 m(SD)	Tobacco Effect	Exposure Effect
VC	4.68(0.67)	4.63(0.64)	5.04(1.02)	4.78(0.91)	P=0.62	P=0.02
FVC	4.35(0.88)	3.63(0.74)	4.49(0.87)	3.82(0.73)	P=0.001	P=0.001
FEV_1	4.73(0.69)	4.73(0.72)	5.12(0.94)	4.85(0.87)	P=0.98	P=0.04
MMEF	3.69(1.27)	3.45(1..11)	3.70(1.11)	3.79(0.99)	P=0.20	P=0.15

C-S, current smokers; N-S, non-smokers; m, mean; SD, standard deviation

Discussion:

Occupational exposure to welding fumes is known to be an important factor in the causation of the symptoms of bronchitis in welders (Akbarkhanzadeh, F., 1979;Antonini, J.M., 2003;James, M., S. Sam, 2007). Welders at the plant with typical occupational health and hygiene problems were exposed to welding fumes that exceeded the recommended TLV. In this study, all of the exposed welders were involved in two welding processes (MMA and MIG). Total fumes and dust were major chemical hazards at work, as they has been reported by other researchers (Akbarkhanzadeh, F., 1979;BOHSC., 1998). Congruent with many studies (James, M., S. Sam, 2007;ATS Statement, 1987), this study confirms that the MS welders have a higher prevalence of respiratory symptoms such as cough, phlegm, dyspnea, and wheezing compared to the control subjects. However, the prevalence of respiratory symptoms were generally higher than those in other studies (BOHSC., 1998;ATS Statement, 1987;International Labour Office Guidelines, 1980). As many investigated have observed prevention, (ATS Statement, 1987;International Labour Office Guidelines, 1980), smokers have respiratory symptoms higher than of smoking controls. In our study MS welder smokers showed a higher rate of cough than nonsmokers. As found in many studies, the systematically higher prevalence of respiratory symptoms in welders may be a consequence of the significant atmospheric exposure to airborne dust found in large amounts in welding fumes (ATS Statement, 1987;Van der wall, J.J., 1990). Many authors have pointed out that the MMA process fumes contained a high proportion of total dust (ATS Statement, 1987;Van der wall, J.J., 1990).The mean values of pulmonary function parameters were different in welders and controls, in which, welders had lower values. The mean FEV_1 values in both smoking and non-smoking groups of welders were less than those of corresponding groups of controls. These differences were significant between the two groups(p<0.001) in case study. The difference in maximal midexpiratory flow between the two groups of smokers, though lower for welders (3.69 vs.3.70), was not significant($p<0.15$).Although lung function of smoking welders decreased ,most studies indicated no change in lung function of non-smoking welders (Cotes, J.E., Feinmann E.L., 1989;Laura M. Beaver, 2009). Consistent with our finding , Chinn and colleagues (Scheepers, P.T., G.A. Heussen, 2008) found a significant decrease in FVC, FEV_1,and PEF. This is also contrary to the results obtained by Hunnicutt *et al.* (1964). Is is significant difference in FVC in 100 welders ,in which 71 of whom were smokers compared the a similar number of control subjects. Many previous studies have also shown no overall effect of welding on lung function relative to the control (Zimmer, A.T., P. Biswas, 2001;McMillan, G.A.G., R.J. Pethybridge, 1984). Similarly, welders involved in engineering (Hatden, S.P., A.C. Pincock, 1984), had no change in height standardized FVC, FEV_1, or PEF and these welders did have good exhaust ventilation in their work stations. Respiratory function measurements for all welders showed that respiratory impairment (restrictive pattern, obstructive pattern, or both) was more prevalent among welders(31.9%) compared to controls (8.8%) ($p<0.05$). In this case, t-test showed the mean value of pulmonary function parameters (VC, FVC, FEV_1) among welders to be less than the control group. These differences were significant ($p<0.001$). The radiography results indicated that the percentage of abnormal X-ray patterns among welders was higher (13.8%) than the control group (2.5%). Meanwhile, the results obtained from the χ^2 test showed that, respiratory symptoms correlated with an abnormal radiography ($p<0.0001$). The incidence of pneumoconiosis has declined drastically in western industrialized countries because of rigorous work place monitoring and control measures, however, it is probably the most common occupational disease in the developing countries. Concerning pulmonary function parameters in both groups (welders and control), the four variables have a positive correlation with age, and height ($P < 0.0001$). The results obtained from the function measurements were analyzed by multiple regression equations. With regards to the analysis, a linear model for predict in of pulmonary functions (Table 5) has been employed. According to this model, it has found verified that the decrease of lung functions is linked to the age among welders and controls. Increasing prevalence of respiratory disorders and the decrement in pulmonary function parameters among MS welders proved that exposure to welding fumes could cause chronic bronchitis.

Table 5: Regression equations of respiratory parameters in controls and welders

Parameter	Regression equation	P value
VC		
Controls	0.0573 H-0.0427 A-3.537	P<0.0001
Welders	0.0387 H-0.0194 A-1.23	P<0.0001
FVC		
Controls	0.0665 H-0.0312 A-5.40	P<0.0001
Welders	0.0319 H-0.0221 A+0.10	P<0.0001
FEV_1		
Controls	0.0579 H-0.0411 A-4.160	P<0.0001
Welders	0.0434 H-0.0258 A-2.749	P<0.0001
MMEF		
Controls	0.047 H-0.0446 A-2.833	P<0.0001
Welders	0.056 H-0.0428 A-5.453	P<0.0001

Conclusion:

In conclusion, this study found that a high level of welding fume was found with a prevalence of cough, phlegm, dyspnea, and wheezing higher among the MS welders than the controls. These conditions were related to welding fumes and concomitant smoking in the workplace. The prevalence of radiologic evidence of pneumoconiosis was high. Lung function impairment in the welders was higher than controls, and results of multiple regression indicated that, age was not a confounding factor. We primarily found that the obstructive pattern of lung impairment in shown by decreased FEV_1, both in smoking and non-smoking welders compared to controls. We have shown a linear model to predict pulmonary functions. The fact that welders in the present study showed decreased pulmonary function and an increased prevalence in respiratory symptoms with no industrial hygiene program in the workplace, while welders working in well designed ventilation areas appear to have less risk of airway obstruction. It is suggested that industrial hygiene programs can be effective in prevention of adverse effects on respiratory health. An additional benefit of this study in a developing country is reduce the potential health risks of welders by providing then with safety information about hazards of their profession. Data (results) obtained from this study demonstrate the need for prevention of exposure and shows the magnitude of the effect in a population.

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