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RESPIRATORY DISORDERS, PULMONARY FUNCTIONS AND RADIOLOGICAL ABNORMALITIES AMONG WORKERS EXPOSED TO WELDING FUMES

By

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Abstract

Introduction: The welding process produces visible smoke that contains harmful metal fume and gas by-products which may have deleterious effects on the respiratory system. **Aim of Work:** To study the prevalence of respiratory symptoms and diseases, and to detect the changes in pulmonary functions and chest X rays among welders. **Materials and Methods:** This cross-sectional study was conducted in the Shuaiba industrial area, Kuwait. Two hundred and thirty-five welders and 155 unexposed workers were interviewed using the British Medical Research Council questionnaire; clinical examination (general and local to the chest) was done. Workers underwent measurements of lung functions, and chest X rays were performed and interpreted, according to the ILO classification of pneumoconiosis. Cases suggestive of pneumoconiosis underwent high-resolution CT scanning. **Results:** Exposure to welding fumes significantly increased the prevalence of chronic cough in the early morning, it was 1.74 times fold higher compared with unexposed workers. Chronic bronchitis was more prevalent among welders, but the result was not statistically significant. Metal fume fever was experienced by 23.4% of the studied welders, the majority reported one or two attacks per year, and

attacks usually lasted for one or two days. The frequency of sick leaves was significantly higher among welders (35.74%) compared with unexposed workers (14.19%), and was mainly due to respiratory diseases, followed by musculoskeletal disorders, and injuries. Lung function indices (LFIs) (FVC, FEV_1, FEV_1%, PEFR, $FEF_{75\%}$, $FEF_{50\%}$, and $FEF_{25\%}$) showed significant decrements among welders after adjusting for age, height, weight, and smoking, moreover, increase in the duration of exposure to welding fumes was significantly associated with a decrease in lung functions after allowing for the effect of confounders. Findings suggestive of pneumoconiosis were observed among welders. **Conclusion:** Welding fumes had significant adverse effects on the respiratory system of welders and safety measures should be encouraged among workers.

Keywords: Welding, Respiratory symptoms, Pulmonary function tests, Radiological changes and Pneumoconiosis.

Introduction

Welding is considered one of the hazardous occupations and is increasing dramatically in both developed and developing countries. The welding process produces a mixture of particulate and non-particulate chemicals including lead, nickel, zinc, iron oxide, copper, cadmium, fluorides, manganese, and chromium. Most of the fumes created from the welding process have particles less than 2μm in aerodynamic diameter, which can penetrate the lungs and be deposited in terminal bronchioles and alveoli (Takahashi et al., 2020).

Occupational exposure to welding fumes may cause acute and chronic respiratory health effects. Acute respiratory effects ranged from airway irritation to asphyxia and pneumonitis (Antonini et al., 2003). Chronic respiratory disorders such as chronic bronchitis, occupational asthma, pneumoconiosis, lung cancer, and reduction of pulmonary function were reported (Vlahovich and Sood, 2021). Benign pneumoconiosis was usually attributed to chronic exposure to iron oxides during the welding process (Grazia et al., 2020).

Although adverse respiratory health effects of welders have been suggested by several research groups, yet findings have not been conclusive (Subhabrata et al., 2018 and Ijaz et al., 2020).

Aim of Work

To study the prevalence of respiratory symptoms and diseases, and the changes in pulmonary functions and chest X-rays among welders

Materials and Methods

Study design: It is a cross-sectional comparative study

Place and duration of the study: The study was conducted at Shuaiba Industrial area, Kuwait; from December 2017 till November 2018.

Study sample: The study population; included all workers exposed to welding fumes at Shuaiba Industrial Area in the State of Kuwait (No=300). Out of 300 welders; 65 did not participate in this study as they did not fulfill inclusion criteria. Inclusion criteria included: duration of work should be for at least six months, not exposed to respiratory hazardous agents other than welding fumes, had no history of any previous occupation causing respiratory hazards, and free from chronic respiratory diseases and/ or systemic diseases that affect the respiratory system.

The remaining 235 welders constituted the inference population with a response rate 78%.

The comparison group was selected randomly from the workers attending the Industrial Medical Center (affiliated to the Shuaiba Industrial Area) for periodic examination and fulfilled the inclusion criteria (155 non exposed workers).

The sample size was calculated using G power statistical test, alpha was considered as 0.05, power (1-*B* error probability) as 0.8, and allocation ratio N_2/N_1=1. The calculated least sample size was 64 welders and 64 unexposed workers.

Study methods

Tools for data collection included:

a) **A self-structured interviewing questionnaire**, to obtain data about sociodemographic and workplace characteristics

b) **British Medical Research Council "BMRC" questionnaire** for respiratory symptoms, diseases and smoking habit.

c) **Clinical examination** (general and local to the chest).

d) **Pulmonary functions tests** were carried out by a computerized flow volume spirometer MasterScreen IOS, which can produce both volume time and flow-volume curves. The spirometer was calibrated daily with a one-liter syringe. The spirometer used and the maneuvers met the recommended standardization cited by the American Thoracic Society

(Bruce et al., 2017).

The following lung function indices were recorded for each worker in the study: FVC, FEV_1, FEV_1/FVC %, PEFR, $FEF_{75\%,}$ $FEF_{50\%,}$ and $FEF_{25\%.}$

e) Standard full-size postero-anterior chest radiographs were taken at full maximal inspiration. Chest radiographs were interpreted according to the ILO classification of pneumoconiosis. Cases suggestive of pneumoconiosis underwent **high-resolution CT scanning** carried out in the radiology unit at the Shuaiba Industrial Medical Center.

Consent

A verbal consent to share in the study was obtained from the participating workers. All collected data were dealt with great confidentiality.

Ethical Approval

This study was approved by Medical Ethics Committee of Alexandria Faculty of Medicine - Alexandria University. Reference number of approval: IORG00012098.

Also, an approval was taken from the Research Committee at Ministry of Health of Kuwait and from the Shuaiba Industrial Area, Kuwait.

Data Management

The data has been coded and registered and the analysis was done using the SPSS package (version 25). For qualitative variables, descriptive statistics were provided as frequencies and percentages, and as mean and standard deviation for quantitative variables. The following tests were used: Chi square, Fisher Exact tests, t-test, F test. Correlation coefficients (r) were used, to assess the degree of association between different variables. Logistic regression analysis was done to explain the relationship between each respiratory symptom and one or more independent variable. P-value $\leq$ 0.05 was considered significant.

Results

All subjects participating in this study were males and most of the welders and unexposed workers were Indians. Welders were significantly younger (mean age 34.77±7.39 versus 39.00±9.05 years t=5.053, p<0.001). Similarly, welders were significantly shorter (t =-2.346, p <0.001) and less obese than unexposed workers (t= 4.375, p< 0.001). Meanwhile, the mean smoking index was significantly higher among unexposed workers compared t exposed (t =-2.346, p<0.001). (Results are not tabulated)

Studying current *workplace characteristics* showed that the job duration of welders ranged from 6 months to 25 years with a mean of 5.183 years, and their daily exposure to welding fumes ranged between 5-11 hours. Most of the welders worked in open space, and they all used PPEs. Flux-cored arc welding with steel alloys was the most common welding method used by the studied welders.

Regarding *sick leaves*, its frequency was significantly higher among welders (35.74%) compared with unexposed workers (14.19%). Sick leaves were mainly due to respiratory diseases, followed by musculoskeletal disorders, and injuries (Results are not tabulated).

Table 1: Distribution of the studied groups according to respiratory symptoms.

Respiratory symptoms	Welders (No =235)				Unexposed workers (No =155)				p-value
	Yes		NO		Yes		NO		
	No	%	No	%	No	%	No	%	
Cough in the early morning in winter	28	11.90%	207	88.10%	7	4.52%	148	95.48%	**0.012***
Chronic cough	5	2.13%	230	97.87%	1	0.65%	154	99.35%	0.405
Phlegm production in the early morning in winter	19	8.09%	216	91.91%	6	3.87%	149	96.13%	0.096
Chronic phlegm production	5	2.13%	230	97.87%	1	0.65%	145	99.35%	0.405
Wheeze	2	0.9%	233	99.1%	2	1.30%	153	98.70%	0.651

*: Significant

Table (1) showed that there was a statistically significant difference between the two groups regarding chronic cough in the early morning (p=0.012). Chronic cough, phlegm production and wheeze were more prevalent among welders compared with unexposed workers but it didn't reach a significant level (p= 0.405, 0.096, 0.405 and 0.651 respectively).

Table (2): Logistic regression model describing respiratory symptoms among the studied population after allowing for the effect of smoking.

Independent variables	Cough in early morning			chronic phlegm			Wheeze		
	B	Exp(B)	95%CI	B	Exp(B)	95%CI	B	Exp(B)	95%CI
Constant	-2.696		---	-2.177		---	-4.234		---
Exposure (Yes, NO)	1.065	**2.902***	1.23-6.84	0.031	0.970	0.92-6.01	0.322	1.380	0.12-15.45
Smoking (Yes, NO)	0.551	**1.736***	0.28-1.19	1.235	0.291	0.24-1.20	1.585	4.878	0.02-2.29

*:Significant B: beta Exp(B): Exponentiation of B coefficient CI: Confidence interval

Table (2) revealed that after allowing for the effect of smoking, the l**ogistic regression model** showed that chronic cough in the early morning among welders was significantly 2.9 times fold higher when compared with unexposed workers. On the other hand, phlegm production and wheeze were more prevalent among welders compared with unexposed workers, yet, the relationship was not statistically significant.

As regards respiratory diseases there was no statistical significant difference between welders and unexposed workers regarding bronchial asthma and chronic bronchitis (p=0.352 and 0.162 respectively). However, about a quarter of welders 23.40% suffered from *Metal fume fever* (MFF) which lasted for one day (43.63%) or two days (47.27%). About 10% of the welders experienced three to six attacks of MFF per year (Results are not tabulated).

Table3: Correlation regression relationship between exposure to welding fumes and lung function indices (LFI) after allowing for age, height, weight, and smoking.

LFI	(Constant)	Height/ m	Weight/kg	Age/years	Smoking	Exposure (1:Yes, 0:NO)	
						β	p
FVC	-5.106	5.824	0.000	-0.027	0.202	-0.145	**0.019***
FEV_1	-3.171	4.184	0.001	-0.026	0.001	-0.182	**<0.000***
FEV_1%	102.364	-11.782	0.004	-0.092	-0.676	-1.931	**<0.000***
PEFR	-3.323	7.356	0.003	-0.024	0.224	-0.039	0.808
$FEF_{75\%}$	-2.139	5.798	0.006	-0.022	0.136	-0.243	0.122
$FEF_{50\%}$	-0.046	2.687	0.005	-0.028	0.003	-0.532	**<0.000***
$FEF_{25\%}$	0.308	0.991	0.000	-0.024	-0.014	-0.245	**<0.000***

FEV1 = Forced expiratory volume in the first second, FVC = Forced vital capacity, PEF= Peak Expiratory Flow, FEF25-75= Forced Expiratory Flow at 25%, 50% and 75%. *: Significant

Table (3) revealed regression models for different *lung function indices* (LFI) as dependent variables and exposure (Yes=1 and NO=0) as an independent variable while allowing for the effects of age, weight, height and smoking (as confounders). The mean values of FVC, FEV_1 and $FEV_{1\%}$ for welders was significantly lower than the unexposed group (β: -5.106, -3.171, 102.364, respectively, and p: 0.019, <0.000, <0.000, respectively). The decreased FEV_1 percent of FVC is consistent with an obstructive impairment.

The mean value of PEFR was significantly lower among welders compared to unexposed subjects (β: -3.323, p: 0.808). The mean value of $FEF_{50\%}$ and $FEF_{25\%}$ (indices of medium and small-sized airway caliber) was significantly lower among welders compared to the unexposed subjects (β: -0.046, and 0.308, respectively and p: <0.000, and <0.000 respectively).

Table 4: Correlation regression relationship between duration of exposure to welding fumes and lung function indices (LFI) after allowing for age, height, weight, and smoking.

LFI	(Constant)	Height/ m	Weight/kg	Age/ years	Smoking	Exposure (years) β	p
FVC	-4.912	5.747	0.001	-0.024	0.197	-0.017	**0.022***
FEV_1	-2.955	4.105	0.002	-0.022	0.135	-0.019	**0.002***
FEV_1%	104.691	-12.641	0.016	-0.048	-0.741	-0.207	**0.001***
PEFR	-3.212	7.299	0.003	-0.023	0.224	-0.009	0.647
$FEF_{75\%}$	-1.743	5.626	0.007	-0.015	0.129	-0.034	0.072
$FEF_{50\%}$	0.518	2.499	0.008	-0.017	-0.016	-0.051	**0.002***
$FEF_{25\%}$	0.519	0.935	0.001	-0.019	-0.023	-0.020	**0.005***

FEV1 = Forced expiratory volume in the first second, FVC = Forced vital capacity, PEF= Peak Expiratory Flow, FEF25-75= Forced Expiratory Flow at 25%, 50% and 75%. *: Significant

Table (4) showed that impairment of lung functions was duration dependent where after allowing for confounders, increased duration of exposure to welding fumes was significantly associated with decease in FVC (β: -4.912 p:0.022), FEV_1 (β: -2.955, p: 0.002), decrease in PEFR (β: -3,212, p: 0.647), and decrease in $FEF_{50\%}$ and $FEF_{25\%}$ (β: 0.518, and 0.519respectively, p: 0.002, 0.005respectively).

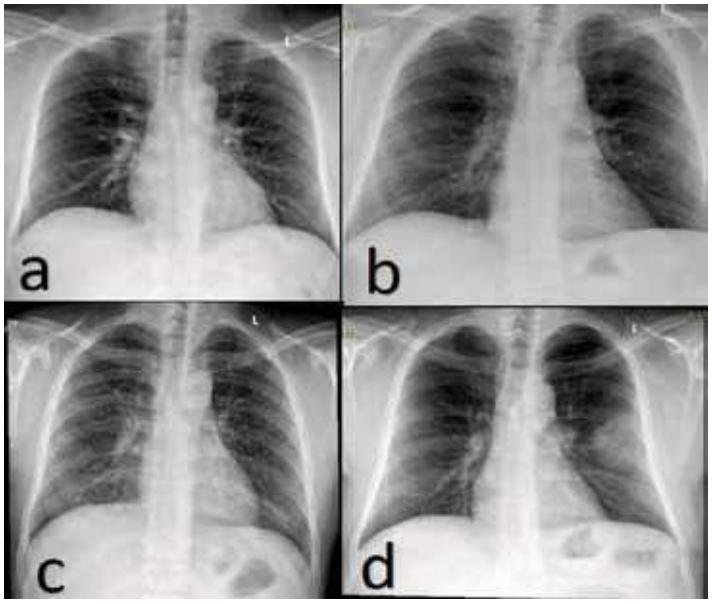

Figure 1: Plain Chest x-ray postero-anterior views in four patients (a) showing bilateral macro and micro-nodular infiltration (2/2 ILO profusion grade, p/p size) with increase broncho-vascular marking and calcified hilar lymph node. (b) showing right macro and micro-nodular infiltration (1/1 ILO profusion grade, t size) with minor bilateral basal reticular and left basal atelectasis.(c) showing bilateral macro and micro-nodular infiltration (2/2 ILO profusion grade, p/q size) with ground glass appearance of interstitial lung disease (e) showing calcified/healed granulomatous process of pneumonia in left lobe and calcified hilar lymph nodes.

Radiological examination indicated 4 chest x-rays with pneumoconiosis. Opacities were small and rounded of size p/p and p/q in two x-rays and profusion degree was 1/1, in the other 2 x-rays the opacities were irregular and of size t and profusion 2/2.

Increased bronchovascular markings were demonstrated in chest x-rays of (91.9%) of the studied welders. Calcified hilar lymph nodes were found in 23 chest x-rays. Random findings of 4 cases of bronchiectasis, 5 cases of atelectasis, 1 case of pneumonia and 1 case of pneumonitis were described (Figure 1).

Findings were confirmed by high resolution computed tomography.

Discussion

There are conflicting data in the literature regarding welding fume exposure and respiratory effects. Thus, the present study was conducted to address such a controversial issue. The present study revealed that the frequency of sick leaves was significantly higher among welders compared with unexposed workers and was mainly attributed to respiratory causes (Results are not tabulated). Similar findings were reported by Fawer et al., (1982) in a study conducted on British welders. On the contrary, evidence from a longitudinal study conducted on 222 welders in the Netherlands stated that musculoskeletal problems were the main cause of sick leave which accounted for 44% of all workdays lost (Burdorf et al., 1998).

The current study demonstrates that exposure to welding fumes has led to a significant increase in the prevalence of chronic cough in the early morning. Phlegm production, wheeze, and shortness of breath were higher among welders but it didn't reach a statistical significance level (Table 1). Moreover, after allowing for the effect of smoking, there was no significant relationship between the type of alloy (iron, steel, mixed) used by the studied welders and the occurrence of chronic cough in the early morning (Table 2). In agreement with the results of this study, Rangkooy et al., (2016) evaluated respiratory symptoms in 60 welders and 40 non-welders in the steel industry, they found that persistent cough was more prevalent among welders compared to non- welders. Hayden et al., (1984) who studied respiratory symptoms among welders in the three largest factories in West Midlands, UK, found no difference between welders and controls as regarding phlegm production wheeze, and shortness of breath. Moreover, a study conducted in Finland showed no significant difference between 157 welders and 108 controls regarding the prevalence of respiratory symptoms (Antti-Poika et al., 1977).

The current study did not confirm an association between exposure to welding fumes and increased prevalence of chronic bronchitis nor asthma. Coinciding with the results of this study, the findings of a Denmark epidemiological study showed no significant difference in the occurrence of chronic bronchitis between welders and controls (Fogh., et al 1969). Similarly, when Zober and Weltle (1985) studied the respiratory effects

of arc welding workers who had an average of 21 years of work experience in Germany. Chronic bronchitis was confirmed only among welders who smoked. Moreover, Sferrazza and Beckett (1991) found through literature review no evidence of occupational asthma caused due to welding fumes exposure.

On the other hand, the findings of a study conducted on Korean shipyard welders supported an association between welding fume exposure and increased risk of COPD (Koh DH et al., 2015). Another study by Al-Otaibi, et al., (2015) who investigated the respiratory health of welders in Saudi Aramco company in 2018, found that chronic bronchitis was significantly more prevalent among welders compared to the unexposed matched group after excluding the effect of smoking. Similarly, a cross-sectional study conducted in a container yard, Sri Lanka; have indicated that chronic bronchitis was significantly higher among welders (27%) than in controls (7%) with an odds ratio of 4.6 (Jayawardana et al., 2009). Moreover, Hannu et al., (2007) confirmed the relation between long term exposure to stainless steel welding fumes and the development of occupational asthma, and the mean duration of exposure before the onset of asthma symptoms was 18 years.

Insignificant results in the current work regarding the prevalence of chronic bronchitis and bronchial asthma among welders may be attributed to the fact that most of welders who participated in this study were relatively young; their age ranged between 20 and 40 years old, and their job duration was less than 10 years (Results are not tabulated). On the other hand, most of the studies that detected asthma were prospective cohort studies, as asthma caused by exposure to welding fumes requires a long time to detect bronchial obstruction and hyper responsiveness.

As regards Metal Fume Fever (MFF); it was experienced by 23.40% of the studied welders, most of them had one or two attacks per year, and attacks usually lasted for one or two days (Results are not tabulated). Coinciding with these results, El-Zein et al., (2005) detected MFF symptoms among 39.2% of welding apprentices. Moreover, at the Victorian Poison information Centre, Australia, they received calls between June 2005 and December 2010 to detect the exposure and symptoms of

metal fume fever. It has been noticed that 95% of calls were symptoms of metal fume fever occurring on Mondays within 24 hours of metal fume exposure among welders using steel and iron alloys. Welders admitted that they had 1-3 attacks per year, and attributed it to poor safety practices and control measures in the workplace (Wong et al., 2012).

The variability in the reported prevalence of Metal Fume Fever (MFF) may be due to the misdiagnosis of MFF with upper respiratory tract infection or influenza, as there is no specific test available for diagnosing metal fume fever. Thus, a detailed occupational history is mandatory.

Multiple regression analysis was used to allow for the effects of confounding variables while examining the relationship between exposure to welding fumes among the studied group and lung functions. It revealed a significant reduction in the mean values of FVC, FEV_1, and FEV_1% .Thus, a mixed restrictive and obstructive pattern was suggested. PEFR and maximum flow rates at 50% and 25% of FVC were recorded and found to be significantly lower among welders compared with unexposed workers (Table 3). Thus, medium and small-sized airways were mainly narrowed. This is consistent with the irritant nature of the welding fumes. Moreover, lung function impairment was also dependent on the duration of exposure to the job (Table 4). There was no significant relationship between the type of alloy used by welders and impairment of lung function parameters (Results are not tabulated).

Coinciding with the results of this study, Rangkooy et al., (2016) found a significant reduction in FVC, FEV_1, $FEF_{75-25\%}$ and FEV_1/FVC ratio, among welders in the steel industry when compared to a non- welders' group. Similarly, an Iranian cohort study in 2011, found that mean values of FVC, FEV_1, FEV_1%, and PEFR were lower among welders compared to office workers, results were not statistically significant, but after adjusting for age and smoking habits, exposure to welding fumes was significantly associated with FEF25-75% reduction. Also, work duration was significantly associated with a decrease in FEV_1, FEV_1%, and FEF25-75% (Sharifian, et al. 2011 and Rahmani et al., 2018). Another study done by Kilburn et al., 1989 who investigated 145 welders from a West Coast shipyard, Los

Angeles, reported a significant decrease in FEF25-75% predicted values compared to controls. Epidemiological studies by Cotes et al., 1989, Chinn, et al., 1990 and Ozdemir, et al., 1995 have stressed on the role of smoking in the impairment of lung functions among welders. Roach LL in 2017 stated that smoking in combination with welding fume exposure had a negative impact on pulmonary functions of young healthy workers. On the contrary, other studies reported no significant relationship between exposure to welding fumes and impaired pulmonary functions (Ozdemir et al., 1995).

The current study revealed radiological abnormalities suggestive of pneumoconiosis in 4 chest x-rays (1.7%) of welders, and the diagnosis was confirmed by high-resolution CT scanning. Increased bronchovascular markings were demonstrated in chest x-rays of (91.9%) of the studied welders which may be attributed to welding fumes and smoking. Moreover, 23 chest X-rays showed calcified hilar lymph nodes suggestive of old tuberculosis (Figure 1).

Matching with the findings of the current results, the appearance of lung opacities on chest x-ray were first reported in asymptomatic welders in 1936 (Spalgais et al., 2020). Attfield and Ross, in 1978 conducted a study on 661 electric arc welders. they demonstrated small rounded opacities of profusion 0/1 or more in chest x-rays of 7% of the welder. Studies conducted on welders by Zober et al., 1985 and Buerke et al., 2003 in Germany showed a high prevalence (27%) of small round opacities of the size 'p' in the chest x-rays. Other researchers suggested that the welder's pneumoconiosis was benign and opacities were completely resolved after cessation of exposure to welding fumes (Lim et al., 2000, Buerke et al., 2003 and Khalid et al., 2009)

Conclusion

The present study provides strong evidence about the association between chronic exposure to welding fumes and the increased frequency of chronic cough in the early morning. Moreover, impairment of lung functions and pneumoconiosis were confirmed. Thus, the results of this study will add to the growing body of evidence about the effects of welding emissions on the respiratory health of welders.

Recommendations

Respiratory surveillance program

should be conducted every two years during the periodic medical examinations which include: clinical examination, lung function testing to evaluate welders' lung condition, chest x-rays for early detection of pneumoconiosis, safety education and promotion to raise awareness about occupational hazards of the welding process, encourage the use personal protective equipment and smoking cessation.

Conflict of Interest

Authors declared that there is no conflict of interest exists.

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