International Journal of Occupational Safety and Ergonomics (*JOSE*) 2013, Vol. 19, No. 4, 647–655

Pulmonary Functions of Welders in Gas Transmission Pipelines in Iran

Farideh Golbabaei
Monireh Khadem
Asghar Ghahri

School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

Mohammad Babai

Occupational Medicine Association, Tehran, Iran

Mostafa Hosseini
Mirghani SeyedSomea

School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

Behnam Dinari

Department of Health, Safety, Environment and Quality, Iranian Gas Engineering and Development Company, Iran

This study evaluated the influence of welding on pulmonary functions in welders. Spirometry tests were performed before and after work shift in 91 welders and 25 clerks (control group). We examined forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), FEV1/FVC ratio and forced expiratory flow 25%–75% (FEF 25–75). Significant differences were found for FVC and FEV1/FVC between welders and the control group in pre- and post-shift measurements ($p < .001$). In welders, smoking and nonsmoking habit had no significant effects on any pulmonary indices before or after shift. Work experience and fume concentrations also had no significant effects on the majority of spirometric indices ($p > .05$). Most welders had at least 1 of the respiratory symptoms. Significant differences were found between pre- and post-shift indices (as percentage of predicted values calculated with spirometer) and between the welders engaged in some welding tasks and the control group before work shift. This study documented work-related changes in pulmonary functions in the welders and marked drops in these functions without symptoms in some welders.

fume   pulmonary functions   pulmonary symptoms   welding   spirometric test

1. INTRODUCTION

It is estimated that more than one million workers worldwide perform some type of welding as part of their work duties [1]. Welding of metals may cause substantial exposure to fume particles and gases. The main components of welding emissions are oxides of metals caused by contact of oxygen in the air and vaporized metals [2]. These particles are particularly hazardous components of welding fumes, they are small enough to be deposited in the terminal bronchioles and alveoli,

This study was supported by grant 795138 from Iranian Gas Engineering & Development Company, Iran. We wish to thank Dr. K. Tobaei for his assistance in spirometric tests. We also appreciate the technical assistance of Mr. M. Fallahi, Mr. D. Eskandari and Mr. A. Mirzaei during air sampling.

Correspondence should be sent to Farideh Golbabaei, School of Public Health and Institute of Public Health Research, Tehran University of Medical Sciences, P.O.Box: 6446-14155, Tehran, I.R. IRAN. E-mail: fgolbabaei@sina.tums.ac.ir.

distal to mucociliary cleaning mechanisms. Electric arc welding processes produce particles with aerodynamic diameters of 0.1–0.5 μm. These particles are predominantly composed of metals, such as iron, nickel, molybdenum, manganese, chromium and their oxides [3].

Many respiratory problems may be associated with welding. Welding fumes may cause acute respiratory effects, including airway irritation, acute bronchitis, metal fume fever after zinc oxide inhalation and, less commonly, hypersensitivity pneumonitis or occupational asthma. Welders are also known to have a higher risk for chronic respiratory disorders such as pneumoconiosis, chronic bronchitis and lung cancer [1, 3, 4, 5, 6, 7].

Spirometry is an important tool for measuring the extent of pulmonary function impairment and for assessing the response to treatment [3]. It assesses the occupational impact on the respiratory function of workers in various occupations, e.g., coal miners, cotton textile workers, welders, farm workers, chemical workers and cement workers [8]. When used in conjunction with the clinical and occupational history and chest radiographs, it helps to determine the nature and severity of lung disease. Periodic retesting of workers can detect pulmonary disease in its earliest stages, when corrective measures are more likely to be beneficial.

The parameters of spirometry are important to provide clinical information, including maximal voluntary ventilation (MVV, formerly called maximal breathing capacity). It is the largest volume of gas that can be moved into and out of the lungs in one minute by voluntary effort. The normal MVV range is 125–170 L/min. MVV depends upon muscular force, compliance of the thoracic wall and lungs, and airway resistance [3].

Other main parameters are forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), FEV1/FVC ratio, maximum expiratory flow when 75% of the vital capacity remain to be expired (MEF75), maximum expiratory flow when 50% of the vital capacity remain to be expired (MEF50) and maximum expiratory flow when 25% of the vital capacity remain to be expired (MEF25) [9].

The aim of this study was to evaluate the influence of welding activity on pulmonary functions in gas transmission pipeline welders in Brojen, Chahar Mahal-o-Bakhtiari province in Iran, and their association with the level of welding fumes in work environments.

2. METHODS

We used spirometric data of 116 persons: 91 manual metal electric arc welders (working for at least 8–10 h a day) and 25 clerks as the control group. A data collection sheet was supplemented by job-specific questions about the duration and extent of welding fume exposure, mechanical and personal work protection devices, the specific welding task type, smoking habit and demographic data. The spirometric data of eligible participants were analyzed.

Spirometry was performed with a SPIROLAB2 spirometer (Medical International Research, Italy) by experienced technicians prior to and after work shift. Each participant was examined by the same technician and with the same equipment. The tests were interpreted by occupational medicine specialist who clarified substantial changes in spirometric indices during work shift.

The values of FVC, FEV1, FEV1/FVC ratio and forced expiratory flow between 25% and 75% of FVC (FEF 25–75) were examined. To compare their relative values (as percentage of predicted values calculated with the spirometer) before and after work shift only the values with differences over 5% (between pre- and post-shift) were analyzed. This could eliminate the meddler effect caused by circadian rhythm during work shift in statistical analyses. Also, data with differences over 10% between pre- and post-shift pulmonary functions were surveyed (some of data with differences under 10% were eliminated from statistical analysis). Thus, only few data remained, as some of them showed abnormal differences (e.g., 37%) and they were not included in the analysis, to minimize the confounding factors.

Workers' exposure to welding fumes was assessed with the method recommended by National Institute for Occupational Safety and Health, using mixed cellulose ester filters

(25 mm, 0.8 μm, SKC, USA) and a personal sampling pump (224-PCMTX8, SKC, USA).

SPSS version 11.5 was used for statistical analysis. Mean values and *SD* of age, height, weight, work experience and smoking habit were computed for both groups. Statistical significance was assessed with Student's *t* test or analysis of variance (ANOVA).

3. RESULTS

Table 1 presents demographic characteristics of all participants. There was no significant difference in age, height and weight between the groups.

Table 2 presents pulmonary function status of welders and the control group in pre- and post-shift measurements. The results of pre-shift pulmonary function tests were normal in 84 welders, while the other 7 welders had some disorders (3 obstructive, 3 restrictive and 1 mixed type). Post-shift pulmonary function tests showed that in 76 welders, functions were normal and 18 welders had disorders (6 obstructive, 4 restrictive and 5 mixed type).

Table 3 shows spirometric data for welders and the control group: the predicted values (calculated with the spirometer) and the pre- and post-shift results expressed in absolute units and as percentage of the predicted values. The pre- and post-shift spirometric values for welders and the control group were compared and the corresponding *p* values are given in Table 3.

In this study, the average exposure to total fumes in welders was 13.12 mg/m^3. Student's *t* test indicated that total fume concentrations were higher

TABLE 1. Characteristics of Welders (*n* = 91) and Control Group (*n* = 25)

Group	Age[a] (years)	Height[a] (cm)	Weight[a] (kg)	Work Experience[a] (years)	Smokers
Welders	30.3 ± 9.17	176.4 ± 6.95	73.5 ± 12.17	4.8 ± 6.42	57
Control	34.9 ± 8.50	173.0 ± 7.76	75.6 ± 12.09	1.7 ± 1.94	6

Notes. a = *M* ± *SD*.

TABLE 2. Pulmonary Function Status in Welders and Control Group

Time	Pulmonary Function	Welders (%)	Control Group (%)
Pre-shift	normal	84 (92)	23 (92)
	obstructive	3 (3)	1 (4)
	restrictive	3 (3)	1 (4)
	mixed	1 (1)	0
Post-shift	normal	76 (84)	20 (80)
	obstructive	6 (7)	3 (12)
	restrictive	4 (4)	2 (8)
	mixed	5 (6)	0

TABLE 3. Pulmonary Function Indices Measured Before and After Work Shift and Predicted Values in Welders and Control Group (*M* ± *SD*)

			Pre-Shift		Post-Shift		
Group	Index	Predicted	Measured	% of Predicted	Measured	% of Predicted	*p**
Welders	FVC (L)	4.97 ± 0.58	4.23 ± 0.75	89.14 ± 12.44	4.11 ± 0.71	80.19 ± 11.52	<.001
	FEV1 (L)	4.15 ± 0.51	3.51 ± 0.63	87.90 ± 11.10	3.35 ± 0.63	78.59 ± 11.69	<.001
	FEF 25–75 (L/s)	4.74 ± 0.53	3.58 ± 1.05	85.54 ± 20.73	3.46 ± 0.94	70.28 ± 18.74	<.001
Control	FVC (L)	4.79 ± 0.61	4.78 ± 0.79	105.06 ± 16.71	4.63 ± 0.94	94.65 ± 15.84	<.001
	FEV1 (L)	3.99 ± 0.52	3.80 ± 0.69	95.43 ± 7.76	3.66 ± 0.75	89.41 ± 7.99	<.001
	FEF 25–75 (L/s)	4.44 ± 0.51	3.6 ± 0.92	85.64 ± 18.75	3.56 ± 0.99	77.34 ± 19.15	<.001

Notes. * = significant differences between pre-shift and post-shift values (as percentage of predicted values). FVC = forced vital capacity, FEV1 = forced expiratory volume in 1 s, FEF 25–75 = forced expiratory flow 25%–75%.

than the threshold limit value proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) and than allowable occupational exposure (AOE-Iran, 1381) for 8 h/day ($p < .001$).

Table 4 demonstrates the pulmonary function indices (as percentage of predicted value) in welders and the control group for pre- and post-shift data. Table 4 also shows a comparison of these indices (p value) between two groups. Significant differences were found for FVC, FEV1 and FEV1/FVC between welders and the control group in pre- and post-shift measurements. There were no significant differences between welders and the control group for FEF 25–75, both in pre- and post-shift values.

Among welders, smoking habit had no significant effects on pulmonary indices, in both pre- and post-shift measurements.

Tables 5–6 show pulmonary function values (percentage of predicted value) in welders based on different work experiences and fume concentrations (pre- and post-shift), respectively. Work experience and fume concentrations have almost no significant effects on the pulmonary function indices. Work experience only was significant for pre-shift FVC expressed as percentage of predicted value (different between 1–3 and >5 years) and fume concentration affected post-shift FVC expressed as percentage of predicted value ($p = .018$).

Table 7 presents clinical findings within the two groups (the welders and the control group). Most welders had at least one of the respiratory symptoms and sputum was significantly more frequent among the welders than in the control group ($p = .006$).

TABLE 4. Pulmonary Function Indices (as Percentage of Predicted Values) in Welders and Control Group (*M* ± *SD*)

Time	Index	Welders	Control Group	*p**
Pre-shift	FVC	86.15 ± 10.45	99.80 ± 10.94	<.001
	FEV1	84.46 ± 11.10	94.82 ± 10.03	<.001
	FEV1/FVC	93.86 ± 10.04	100.77 ± 6.47	<.001
	FEF 25–75	77.29 ± 21.10	83.35 ± 16.59	*ns*
Post-shift	FVC	82.39 ± 9.75	96.99 ± 13.65	<.001
	FEV1	80.41 ± 10.98	91.87 ± 10.95	<.001
	FEV1/FVC	92.22 ± 10.01	100.83 ± 9.50	<.001
	FEF 25–75	74.32 ± 18.79	82.65 ± 19.55	*ns*

Notes. * = significant differences between welders and the control group. FVC = forced vital capacity, FEV1 = forced expiratory volume in 1 s, FEF 25–75 = forced expiratory flow 25%–75%.

TABLE 5. Pulmonary Function Indices (as Percentage of Predicted Values) in Welders With Different Work Experience

		Work Experience (years)				
Time	Index	<1	1–3	3–5	>5	*p**
Pre-shift	FVC	86.79 ± 8.90	80.72 ± 13.92	94.65 ± 8.96	86.40 ± 9.42	.022
	FEV1	86.15 ± 10.45	84.41 ± 10.84	82.14 ± 11.76	87.83 ± 9.48	*ns*
	FEV1/FVC	92.89 ± 10.65	97.38 ± 9.43	88.46 ± 9.97	94.17 ± 9.53	*ns*
	FEF 25–75	78.02 ± 23.02	76.32 ± 17.32	71.69 ± 23.07	78.02 ± 21.04	*ns*
Post-shift	FVC	82.71 ± 9.67	80.83 ± 11.21	90.44 ± 4.49	81.51 ± 9.54	*ns*
	FEV1	80.56 ± 10.40	81.42 ± 12.28	85.16 ± 7.31	79.21 ± 11.52	*ns*
	FEV1/FVC	72.99 ± 6.54	78.12 ± 9.23	72.58 ± 5.43	72.60 ± 7.41	*ns*
	FEF 25–75	76.38 ± 19.88	67.89 ± 18.42	74.41 ± 15.50	75.05 ± 18.46	*ns*

Notes. * = significant differences in pulmonary functions between welder subgroups with different work experience. FVC = forced vital capacity, FEV1 = forced expiratory volume in 1 s, FEF 25–75 = forced expiratory flow 25%–75%.

TABLE 6. Pulmonary Function Indices (as Percentage of Predicted Values) in Welders Based on Fume Concentrations ($M \pm SD$)

Time	Index	Fume Concentration Below TLV[1]	Fume Concentration Above TLV	p
Pre-shift	FVC	84.25 ± 9.88	88.95 ± 8.56	*ns*
	FEV1	83.91 ± 9.50	85.71 ± 10.38	*ns*
	FEV1/FVC	94.57 ± 6.67	91.85 ± 9.58	*ns*
	FEF 25–75	79.72 ± 16.11	76.04 ± 21.33	*ns*
Post-shift	FVC	79.70 ± 9.83	85.32 ± 8.37	.018
	FEV1	78.85 ± 10.56	82.11 ± 9.35	*ns*
	FEV1/FVC	92.69 ± 6.41	89.77 ± 8.34	*ns*
	FEF 25–75	72.06 ± 18.31	74.70 ± 18.99	*ns*

Notes. 1 = total fume threshold limit value (TLV) = 5 mg/m^3, FVC = forced vital capacity, FEV1 = forced expiratory volume in 1 s, FEF 25–75 = forced expiratory flow 25%–75%.

TABLE 7. Prevalence of Respiratory Symptoms in Welders and Control Group

Symptom	Welders (%)	Control Group (%)	p
Cough	21 (23)	4 (16)	*ns*
Sputum	40 (44)	3 (12)	.006
Dyspnea	19 (21)	2 (8)	*ns*
Rale	18 (20)	1 (4)	*ns*

A statistical analysis was also performed for pulmonary function indices expressed as % of predicted values in subgroups based on welding task types (Tables 8–9). There were significant differences in pre-shift FVC values for foreman, assistance in fitting, full pass, filling, and brushing and grinding in comparison with the control group. For FEV1, comparisons show significant differences for foreman and filling tasks only (Table 8). Significant post-shift differences in FVC and FEV1 were also found between the welders and the control group in some welding tasks (Table 9).

4. DISCUSSION

In the present study, many differences in the pulmonary function indices expressed as percentage of predicted values (pre- and post-shift) between the welders and the control group were statistically significant. By contrast, some studies have reported unaffected spirometric parameters after welding. Wolf, Pirich, Valic, et al. indicated that some parameters (FVC, FEV1) did not differ from those obtained in the control group [7].

Sobaszek, Edme, Boulenguez, et al. reported that there was no influence of the specific welding processes on the spirometric parameters, but a decrease in spirometric values after 25 years of welding activity was evident [10]. In Meo's survey, welding workers with exposures longer than 5 years showed a significant reduction in the values of spirometric indices (FEV1, FEV1/FVC and peak expiratory flow), relative to the control group [5]. Therefore our findings are in accordance with most of studies in which welders had decreased spirometric values in comparison with control groups [11, 12, 13, 14]. Apparent disparities in the studies of pulmonary functions in welders could be attributed to differences in smoking habit, welding material used, suitability of ventilation (local exhaust ventilation) and usage of protective measures. In the present study, significant differences were in the spirometric indices expressed as percentage of predicted values before and after work shift in welders ($p < .001$).

It is noteworthy that the circadian rhythm can influence the pulmonary function indices by ~5%. Investigations show that the endogenous circadian pacemaker contributes to diurnal changes in pulmonary function [15].

We think that working conditions such as high load of welding gases and increased exposure to fumes during work shift can cause significant differences in percentage of predicted values recorded before and after the work shift in welders. The changes in lung function during a work shift perhaps were potentiated by repeated exposure to a sensitizing agent, leading to bronchial hyper-responsiveness.

TABLE 8. Pulmonary Function Indices in Welders and Control Group Based on Task Types in Pre-Shift Measurements (*M* ± *SD*)

Index	Welding Task	Predicted Values	Pre-Shift/Predicted (%)	*p**
FVC (L)	foreman	5.15 ± 0.62	78.92 ± 10.87	.002
	fitting	4.52 ± 0.56	87.74 ± 10.80	*ns*
	assistance in fitting	4.82 ± 0.37	75.23 ± 5.19	.001
	full pass	5.03 ± 0.68	85.83 ± 9.14	<.001
	filling	4.88 ± 0.49	86.85 ± 9.60	<.001
	cap filling	5.13 ± 0.61	90.39 ± 8.65	*ns*
	grinding and brushing	4.92 ± 0.60	83.50 ± 13.27	.001
	back welding	5.20 ± 0.42	93.50 ± 11.65	*ns*
	control	4.79 ± 0.62	99.80 ± 10.94	
FEV1 (L)	foreman	4.23 ± 0.54	75.50 ± 7.53	.013
	fitting	3.64 ± 0.45	87.91 ± 15.41	*ns*
	assistance in fitting	3.98 ± 0.26	80.31 ± 6.90	*ns*
	full pass	4.17 ± 0.58	85.02 ± 10.38	*ns*
	filling	4.11 ± 0.45	83.45 ± 10.76	.006
	cap filling	4.30 ± 0.52	85.94 ± 11.87	*ns*
	grinding and brushing	4.13 ± 0.51	84.59 ± 10.28	*ns*
	back welding	4.36 ± 0.33	96.84 ± 22.17	*ns*
	control	3.99 ± 0.52	94.82 ± 10.03	
FEF 25–75 (L/s)	foreman	4.80 ± 0.72	64.31 ± 12.35	*ns*
	fitting	3.99 ± 0.33	77.93 ± 23.01	*ns*
	assistance in fitting	4.64 ± 0.13	84.37 ± 19.32	*ns*
	full pass	4.71 ± 0.54	79.39 ± 19.09	*ns*
	filling	4.75 ± 0.46	75.47 ± 21.53	*ns*
	cap filling	4.87 ± 0.52	76.88 ± 22.97	*ns*
	grinding and brushing	4.78 ± 0.59	78.82 ± 22.60	*ns*
	back welding	4.94 ± 0.21	88.64 ± 35.35	*ns*
	control	4.44 ± 0.51	83.35 ± 16.59	

Notes. Statistic significance ($p < .05$) assessed by ANOVA. * = pre-shift/predicted vs. control), FVC = forced vital capacity, FEV1 = forced expiratory volume in 1 s, FEF 25–75 = forced expiratory flow 25%–75%.

Work experience in welding is a significant factor in some studies [16, 17], but in our study this factor has almost no influence on pulmonary functions, similarly to earlier reports by Ozdemir, Numanoğlu, Gönüllü, et al. [9] and McMillan and Heath [18]. Only in the pre-shift FVC expressed as percentage of predicted value, the difference between the welders working for 1–3 years and for >5 years was significant. This could be possibly due to a younger exposure group and relatively lower work duration in our study.

In the present study, fume concentration affected post-shift FVC expressed as percentage of predicted values. It is worth noting that our welders worked in open spaces so working conditions (e.g., air flow velocity) could influence their exposure to fumes and, consequently, the induced respiratory symptoms.

Respiratory function measurements for all welders showed that respiratory impairment (restrictive, obstructive or mixed) was more prevalent among welders, compared to the control group. This result is in accordance with Pourtaghi, Kakooei, Salem, et al. [19]. The frequency of respiratory symptoms, especially sputum, was greater in the welders than in the control group.

TABLE 9. Pulmonary Function Indices in Welders and Control Group Based on Task Types in Post-Shift Measurements (*M* ± *SD*)

Index	Welding Task	Predicted Values	Post-Shift/Predicted (%)	*p**
FVC (L)	foreman	5.15 ± 0.616	80.31 ± 12.39	*ns*
	fitting	4.52 ± 0.564	94.17 ± 8.78	*ns*
	assistance in fitting	4.82 ± 0.368	75.74 ± 7.34	.011
	full pass	5.03 ± 0.677	81.42 ± 10.33	<.001
	filling	4.88 ± 0.488	81.81 ± 9.52	<.001
	cap filling	5.13 ± 0.611	83.23 ± 9.50	.001
	grinding and brushing	4.92 ± 0.596	81.19 ± 7.77	.001
	back welding	5.20 ± 0.424	87.34 ± 13.36	*ns*
	control	4.79 ± 0.618	96.99 ± 13.65	
FEV1 (L)	foreman	4.23 ± 0.54	72.69 ± 10.82	.021
	fitting	3.64 ± 0.45	85.60 ± 21.19	*ns*
	assistance in fitting	3.98 ± 0.26	80.32 ± 7.04	*ns*
	full pass	4.17 ± 0.58	79.07 ± 12.11	.008
	filling	4.11 ± 0.45	79.44 ± 9.74	.004
	cap filling	4.30 ± 0.52	81.23 ± 10.74	.005
	grinding and brushing	4.13 ± 0.51	82.85 ± 7.53	*ns*
	back welding	4.36 ± 0.33	86.19 ± 18.15	*ns*
	control	3.99 ± 0.52	91.87 ± 10.95	
FEF 25–75 (L/s)	foreman	4.80 ± 0.72	61.96 ± 13.08	*ns*
	fitting	3.99 ± 0.33	88.63 ± 35.99	*ns*
	assistance in fitting	4.64 ± 0.13	64.59 ± 9.76	*ns*
	full pass	4.71 ± 0.54	71.41 ± 18.16	*ns*
	filling	4.75 ± 0.46	75.49 ± 18.97	*ns*
	cap filling	4.87 ± 0.52	75.38 ± 20.60	*ns*
	grinding and brushing	4.78 ± 0.59	79.00 ± 17.86	*ns*
	back welding	4.94 ± 0.21	77.13 ± 26.18	*ns*
	control	4.44 ± 0.51	82.65 ± 19.55	

Notes. Statistic significance ($p < .05$) assessed by ANOVA. * = pre-shift/predicted vs. control, FVC = forced vital capacity, FEV1 = forced expiratory volume in 1 s, FEF 25–75 = forced expiratory flow 25%–75%.

The findings are in accordance with some other studies, in which welders had a higher prevalence of respiratory symptoms than control groups [9, 12, 20, 21].

It is known that respiratory symptoms may be increased in welders who smoke, compared with nonsmoking welders of similar age. However, in our study, smoking and nonsmoking habit in the welders had no significant effect on their pulmonary function indices. In chronic exposures, it has often been difficult to differentiate between the effects due to occupation and those due to cigarette smoking, although cigarette smoking may potentiate the effects of fume inhalation.

Welding task type can also affect exposure to fumes. Differences in spirometric values between welders performing different tasks, especially full pass, filling and cap filling, were significant. In some tasks, such as back welding, welders have to work in confined spaces, resulting in high exposure to fumes. Nevertheless, in our study, there was no significant difference for back welders, because they worked shorter than others and fewer workers performed this task.

Generally, respiratory symptoms and reduced pulmonary functions were more frequent in the welders, compared to the control group. Also, in the present study, obstructive and restrictive lung disorders were more frequent in the welders than in the control group.

In summary, this study documented work-related changes in pulmonary functions in the welders and substantial drops in these functions without symptoms in some welders. In addition, based on other studies, cigarette smoking may potentiate the effects of fume inhalation. Also work history could have an important role in creation of symptoms in welders. Our study did not provide evidence for this, probably because the majority of tested welders had a short history of smoking (several months for some of them) and they worked for only a few years as welders. On the other hand, the type of welding, time spent on welding, welding task type, materials and working conditions are important.

We believe that a strong effort should be made to persuade welders to stop smoking, whereas control measures (e.g., engineering controls like local exhaust ventilation) should be attained and welders should wear respiratory protective devices. Proper information should be provided for welders about hazards of their work and employers must be informed about industrial hygiene programs at workplaces. Finally, further studies are necessary to clarify the roles of welding task type, welding in confined spaces and higher susceptibility of some workers to the effects of welding fume exposure. In fact, welding produces not only fumes but also some toxic gases (e.g., ozone, carbon monoxide and nitrogen dioxide), which can affect pulmonary functions, so investigating effects of welding gases on pulmonary functions is recommended.

REFERENCES

1. El-Batanouny MM, Amin Abdou NM, Salem EY, El-Nahas HE. Effect of exercise on ventilator function in welders. Egyptian Journal of Bronchology. 2009;3(1):67–73. Retrieved August 22, 2013, from: http://www.essbronchology.com/journal/june_2009/PDF/7-mohamed_el-batanony.pdf.
2. Erkinjuntti-Pekkanen R, Slater T, Cheng S, Fishwick D, Bradshaw L, Kimbell-Dunn M, et al. Two year follow up of pulmonary function values among welders in New Zealand. Occup Environ Med. 1999; 56(5):328–33. Retrieved August 22, 2013, from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1757732/.
3. Hayden SP, Pincock AC, Hayden J, Tyler LE, Cross KW, Bishop JM. Respiratory symptoms and pulmonary function of welders in the engineering industry. Thorax. 1984;39(6):442–7. Retrieved August 22, 2013, from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC459827/.
4. Christensen SW, Bonde JP, Omland Ø. A prospective study of decline in lung function in relation to welding emissions. J Occup Med Toxicol. 2008;3:6. Retrieved August 22, 2013, from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2288600/.
5. Meo SA. Spirometric evaluation of lung function (maximal voluntary ventilation) in welding workers. Saudi Med J. 2003;24 (6):656–9.
6. Al-Shamma YMH, Dinana FM, Dosh BA. Physiological study of the effect of employment in old brick factories on the lung functions of their employees. Journal of Environmental Studies. 2009;1:39–46, 2013, from: http://www.jes.sohag.edu.eg/Vol.%20I.%201/Vol.%20I.%2039-46.pdf.
7. Wolf C, Pirich C, Valic E, Waldhoer T. Pulmonary function and symptoms of welders. Int Arch Occup Environ Health. 1997;69(5):350–3.
8. Government of Alberta, Employment and Immigration. Welder's guide to the hazards of welding gases and fumes. Workplace Health and Safety Bulletin (CH032—Chemical Hazards). Edmonton, AB, Canada: Queen's Printer; 2009. Retrieved August 22, 2013, from: http://humanservices.alberta.ca/documents/WHS-PUB_ch032.pdf.
9. Ozdemir O, Numanoğlu N, Gönüllü U, Savaş I, Alper D, Gürses H. Chronic effects of welding exposure on pulmonary function tests and respiratory symptoms. Occup Environ Med. 1995;52(12):800–3. Retrieved

August 22, 2013, from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1128380/.

10. Sobaszek A, Edme JL, Boulenguez C, Shirali P, Mereau M, Robin H, Haguenoer JM. Respiratory symptoms and pulmonary function among stainless steel welders. J Occup Environ Med. 1998;40(3):223–9.
11. Brand P, Gube M, Gerards K, Bertram J, Kaminski H, John AC, et al. Internal exposure, effect monitoring, and lung function in welders after acute short-term exposure to welding fumes from different welding processes. J Occup Environ Med. 2010;52(9):887–92.
12. Loukzadeh Z, Sharifian SA, Aminian O, Shojaoddiny-Ardekani A. Pulmonary effects of spot welding in automobile assembly. Occup Med (Lond). 2009;59(4):267–9. Retrieved August 22, 2013, from: http://occmed.oxfordjournals.org/content/59/4/267.long.
13. Meo SA, Azeem MA, Subhan MM. Lung function in Pakistani welding workers. J Occup Environ Med. 2003;45(10):1068–73.
14. Fidan F, Unlü M, Köken T, Tetik L, Akgün S, Demirel R, Serteser M. Oxidant-antioxidant status and pulmonary function in welding workers. J Occup Health. 2005;47(4):286–92.
15. Spengler CM, Shea SA. Endogenous circadian rhythm of pulmonary function in healthy humans. Am J Respir Crit Care Med. 2000;162(3 Pt 1):1038–46. Retrieved August 22, 2013, from: http://www.atsjournals.org/doi/pdf/10.1164/ajrccm.162.3.9911107.
16. Rastogi SK, Gupta BN, Husain T, Mathur N, Srivastava S. Spirometric abnormalities among welders. Environ Res. 1991;56(1):15–24.
17. Barhad B, Teculescu D, Crăciun O. Respiratory symptoms, chronic bronchitis, and ventilatory function in shipyard welders. Int Arch Occup Environ Health. 1975;36(2):137–50.
18. McMillan GH, Heath J. The health of welders in naval dockyards: acute changes in respiratory function during standardized welding. Ann Occup Hyg. 1979;22(1):19–32.
19. Pourtaghi GH, Kakooei H, Salem M, Pourtaghi F, Lahmi MA. Pulmonary effects of occupational exposure to welding fumes. Aust J Basic Appl Sci. 2009;3(4);3291–6.
20. Luo JC, Hsu KH, Shen WS. Pulmonary function abnormalities and airway irritation symptoms of metal fumes exposure on automobile spot welders. Am J Ind Med. 2006;49(6):407–16.
21. Fishwick D, Bradshaw LM, Slater T, Pearce N. Respiratory symptoms, across-shift lung function changes and lifetime exposures of welders in New Zealand. Scand J Work Environ Health. 1997;23(5):351–8.