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Research article

Association between Pulmonary Function Tests and Spot Welding

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ABSTRACT

Automotive industry is a major industry in Iran with many spot welders. Some studies have shown that automobile factory workers exposed to the aerosols produced during resistance spot welding develop respiratory disorders and symptoms. This study was conducted to evaluate the effect of exposure to spot welding fumes on pulmonary function and respiratory symptoms among spot welders of an automobile factory in Iran.This cross-sectional study was conducted on 1106 male workers of an automobile factory in Tehran, Iran in 2014 including 567 spot welders and 539 non-welding workers which were examined in terms of respiratory symptoms and pulmonary function. Workers with at least five years of work history were enrolled in our study. Welding fume concentrations in the workplace were estimated using NIOSH 7300. The mean (±SD) age and working history of spot welders were 35.16 (±3.51) and 11.05 (±3.15) years, respectively. There was no significantly difference of pulmonary function parameters between two groups. In spot-welders, FEF25-75% correlated inversely with years of experience in the job. A total of 5.2% of participants had at least one respiratory symptom, and the two groups were not significantly different in this regard. The frequency of obstructive pattern was higher in spot welders in comparison with the control group, although the difference was not statistically significant. Although the frequency of obstructive pattern was higher in spot welders, no significant correlation was found between two groups in respiratory symptoms and reduction of pulmonary function parameters; however, this finding may be due to healthy worker effect. Cohort studies should be conducted in order to properly determine the effects of spot welding on pulmonary function.

Keywords: welding, respiratory function test, respiratory symptoms

INTRODUCTION

Welding is a major operation in industries that is widely used in manufacturing industries and construction [1]. Welders' health may be affected by physical and chemical hazards during welding. Common chemical risk factors in welding include fumes and gases, such as carbon monoxide, nitrogen oxide and ozone [2]. Welders are therefore exposed to inhalation of a number of different types of fumes and gases [3]. Metal oxides are the main aerosols released during welding and due to their small size sediment in terminal bronchioles and alveoli away from mucociliary clearance mechanisms [4]. Various respiratory disorders may develop in welders, including acute respiratory effects such as airway inflammation, acute bronchitis, metal fume fever (MFF), occupational asthma and chronic respiratory effects such as chronic bronchitis and lung cancer [1, 4]. Numerous studies have reported the adverse effects of the exposure to welding fumes on pulmonary function [5, 6]. Some studies have shown that welding has a limited effect on pulmonary function, but pulmonary dysfunction may be developing in the more vulnerable welders or those working under special circumstances or in places with a high level of exposure or low ventilation [7]. Some other studies have shown that smoking and occupational exposure to welding fumes have synergistic effects on the incidence of pulmonary dysfunction [6, 8]. Other studies have reported an increase in the frequency of respiratory symptoms and absenteeism in welders due to respiratory disease [1].

The increased risk of chronic obstructive pulmonary disease (COPD) has been noted in many studies [9-11]. Some studies have reported pulmonary symptoms, such as cough, sputum, wheeze, shortness of breath, restrictive and obstructive pulmonary dysfunction in welders [3, 12]. Periodical assessment of pulmonary function is therefore an essential part of the medical surveillance programs in welders [1].

Resistance spot welding is an efficient joining process widely used, especially in the automotive industry. This welding technique is mainly used in this industry to attach automobile body sheets. In this type of welding, contact surfaces are connected through one or more spots.

These welding-spots are created through the heat produced by the electrical resistance against the flow of electric current among pieces. In this type of welding, the base metal does not melt completely, and no electrode is used to fill the gap between the two welded pieces. Considering that no electrode is used and the base metal does not melt in this welding technique, less fume is produced, therefore the risk of pulmonary damage can be reduced. Consequently, spot welding is less harmful than other types of welding.

Nonetheless, several studies have shown that automobile factory workers exposed to the aerosols produced during resistance spot welding develop respiratory disorders, such as reduced pulmonary function, airway inflammation and pulmonary symptoms such as bronchitis [3, 13]. Until recently no studies have yet shown that spot welding has no effect on pulmonary function, so we can’t say that spot welding definitely causes pulmonary complications.

Spot welding leads to the production of ozone, nitrogen oxide and welding fumes, and if the pieces are greased, the grease on their surface gets decomposed during welding and leads to the production of aldehydes that may thus cause inflammation in the respiratory, olfactory and visual systems [14, 15].

Numerous studies have shown that adverse health effects is not only due to the type of aerosols inhaled but also the size and surface are important [16, 17]. One study revealed that ultrafine aerosols less than 100 nm in diameter are often released during resistance spot welding. As a result, although the production of aerosols is rather low in this type of welding, the process cannot be considered absolutely riskless due to the small size of the aerosols produced, and further studies should be conducted on this topic [18].

A study conducted on the concentration of aerosols in an automobile factory showed that spot welding is a major source of aerosol release in factories [19]. Lee et al., reported a case of occupational asthma caused by spot welding fumes [20].

The automotive industry is a major industry in Iran and many spot welders are engaged in it. Given the different results of previous studies, the present study was conducted to examine the effect of exposure to spot welding fumes on pulmonary function and respiratory symptoms in spot welders of an automobile factory in Iran.

MATERIAL & METHODS

The present cross-sectional study was conducted on 1106 male workers of an automobile factory in Tehran, Iran in 2014. The participants included 567 spot welders as the case group and 539 other workers as the control group, which consisted of 197 press brake operators and 342 assemblers who had no exposure to welding fumes and respiratory pollutants but under the same physical work conditions as the spot welders.

The participants were analyzed in terms of their results of spirometry findings and respiratory symptoms.

The annual concentration of iron, zinc, copper and lead fumes were measured in the spot welders' workplace using National Institute of Occupational Safety and Health (NIOSH) 7300 [21].

The inclusion criterion for both groups was having at least five years of experience in the current job position. Subjects were excluded from the study if they had a history of respiratory diseases such as asthma, bronchitis, emphysema, bronchiectasis, lung cancer…or any other chronic condition and exposure to other respiratory pollutants such as asbestos, silica, paint and solvents, and also any experience of welding or exposure to welding fumes in the control group.

Demographic characteristics including age, marital status, type of job, years of employment, smoking habits, history of respiratory symptoms such as cough, dyspnea or shortness of breath, sputum and wheezing were received from the participants. Respiratory function tests were assessed using a calibrated spirometer (Spirolab III Mir) for all participants under similar conditions from 8am to 12pm on the free day of their work schedule and according to ATS (American Thoracic Society criteria) [22].

The parameters FEV1/FVC, FEV1, FVC and FEF25-75 were measured as both crude values and percent of predicted values using NHANES III reference values. The predicted FVC and FEV1<80%, FEV1/FVC ratio <70% and FEF25-75 <50% were considered abnormal.

Abnormal FEV1/FVC either alone or along with abnormal FEV1 was taken to indicate obstructive pattern. Abnormal FEV1 alone was taken to indicate isolated FEV1 reduction. Abnormal FVC was taken to indicate restrictive pattern. Reduction in FEV1/FVC ratio, FEV1 and FVC were considered as mixed pattern.

The collected data was analyzed by SPSS software version 20.

Chi square test was used for determination of association between two qualitative variables, while independent sample t–test was used for evaluation difference between quantitative variables.

P-values < 0.05 were considered significant. This study was approved by the Ethics Committee of Tehran University of Medical Sciences. (Ethical code: IR.TUMS.VCR.REC.1395.653)

RESULTS

A total of 1106 people were enrolled in this study, including 567 spot welders (51.3%) as the case group and 539 non-welding workers (48.7%) as the control group, which itself consisted of 197 press brake operators (17.8%) and 342 assemblers (30.9%). The participants working schedules was around 40 hours/week (8 hours/day)

The average concentrations of iron, copper, lead and zinc fumes were 0.241, 0.047, 0.00956 and 0.011 mg/m3 respectively, and the mean metal fume concentrations were less than ACGIH TLV [23].

The mean duration of service was 11.05 years (range: 5-22) in exposed group and 11.28 years (range: 5-30) in control group. The mean age of exposed group was 35.16 ± 3.51 years (range: 25-50) while in the control group was 5.92 ± 4.75 years (range: 26-54).

Table 1 presents the demographic characteristics of study population. The two groups were similar in terms of BMI and duration of service, but were different in smoking status and age.

Table 1- Demographic characteristics of study subjects

	Spot Welders (Mean±SD)	Non Welders (Mean±SD)	P-Value
Height (m)	175.31±6.27	175.10±6.22	0.570
Weight (kg)	80.89±11.27	81.42±13.67	0.476
BMI (kg/m)	26.29±3.24	26.52±4.00	0.305
Age (year)	35.16±3.51	35.92±4.75	0.002
Duration of service(year)	11.05±3.15	11.28±4.28	0.313
Smoking (pack/year)	0.89±3.03	1.31±3.86	0.0407
Smokers (%)	125(22.04%)	151(28.01%)	0.022

SD: Standard Deviation

As shown in Table 2, there was no significant difference between two groups on pulmonary function tests except for FVC.

The comparison of the frequency of abnormal FVC, FEV1, FEV1/FVC and FEF25-75 between two groups showed the lack of significant intergroup differences.

Linear regression analysis was performed to eliminate confounding effect of smoking and showed no significant difference between two groups.

Only 5.2% of the participants reported at least one of the respiratory symptoms (5.7% in the case and 5.2% in the control group) and there was no significant difference between two groups in this regard (P= 0.733).

Pulmonary function indices as percent of predicted values also compared between two groups.

FEV1, FVC and FEV1/FVC were not associated with duration of employment except for FEF25-75 (P= 0.048).

The frequency of abnormal FVC, FEV1, FEV1/FVC and FEF25-75 was compared between smokers and non-smokers, but only the frequencyof abnormal FEV1/FVC differed significantly between two groups (P= 0.002), although the difference was not significant per se in the case group. So smoking did not significantly affect pulmonary function parameters in the spot welders when assessed alone.

Overall, 506 (89.24%) of exposed group and 476 (88.31%) of the controls showed normal spirometric patterns. Obstructive spirometric pattern was observed in 24 (4.23%) of the spot welders and 17 (3.15%) of the controls, and isolated FEV1 reduction was observed in 22 (3.88%) of the spot welders and 15 (2.78%) of the controls. Restrictive spirometric pattern was observed in 14 (2.46%) of the spot welders and 30 (5.56%) of the controls, and one participant had mixed spirometric pattern in each group.

Not taking in to account two participants with mixed spirometric pattern, 60 spot welders and 62 controls (making for a total of 122 subjects) had an abnormal spirometric pattern. To compare two groups, participants with obstructive spirometric pattern and isolated FEV1 reduction were placed in one group, and those with restrictive spirometric pattern were placed in another group. Table 3 compare two groups in terms of the frequency of abnormal patterns.

In the two groups with obstructive and restrictive spirometric pattern, the pulmonary function parameters did not significantly correlate with length of service. The participants with restrictive spirometric pattern in both groups were similar in terms of smoking (pack/year).

However, in participants with obstructive spirometric pattern this frequency was higher in the controls compared to the cases (p=0.035).

Table 2- A comparison of pulmonary function parameters between spot welders and control group

	Spirometric parameters	Spot welders	Non welders	P value
Observed Values	FVC(L)	4.98±0.69	4.89±0.67	**0.043**
	FEV1(L)	3.92±0.58	3.87±0.53	**0.131**
	FEV1/FVC (%)	78.95±5.27	79.30±5.13	**0.266**
	FEF25-75(L/s)	3.74±0.97	3.72±0.90	**0.765**
Predicted Values (%)	FVC	95.15±10.10	94.31±10.53	**0.179**
	FEV1	93.13±11.11	92.80±10.86	**0.613**
	FEV1/FVC	78.95±5.27	79.30±5.13	**0.266**
	FEF25-75	90.90±23.32	91.86±21.86	**0.480**

Table 3- A comparison of the participants with abnormal spirometric pattern between two groups (122 people)

Spirometric pattern	Spot welders	Non-welders	P value
Obstructive & Isolated ↓FEV1	46 (76.6%)	32 (51.6%)	**0.004**
Restrictive	14 (23.3%)	30 (48.3%)	
Total	60	62	

DISCUSSION

The pulmonary function parameters and the frequency of respiratory symptoms did not differ significantly between two groups. However, the frequency of obstructive pattern was higher in the spot welders in comparison with the control group. Moreover, FEF25-75% was lower in spot welders and its reduction was correlated with longer duration of service.

Few studies have examined pulmonary effects of spot welding and there is not sufficient evidence that spot welding causally related to pulmonary dysfunction.

In 2007; Loukzadeh et al., examined 137 spot welders and 129 office workers, working in an Iranian automobile factory and reported a significant reduction in the pulmonary function parameters FVC, FEV1, FEV1/FVC and FEF25-75 and a higher frequency of obstructive pattern and also higher prevalence of respiratory symptoms in the spot welders compared to the control group. In this study, exposure to welding fumes was within the ranges approved by the ACGIH guidelines [24]. Although the sample size of the present study was several times higher than that of the study of Loukzadeh et al., no significant correlation was observed between spot welding and the spirometric indexes.

In a study conducted in 1999 by Jiin-Chyuan J.L et al., in an automobile factory, mean FVC and FEV1 indexes were significantly lower in the spot welders compared to controls. The study found a significant dose-response relationship between spot welding and obstructive and restrictive pulmonary disorders as well as airway inflammation symptoms (cough, sputum and chronic bronchitis) even though after eliminating the effect of other factors, such as smoking. The spot welders with high exposure were at higher risk of airway inflammation, obstructive and restrictive pulmonary disorders [3]. The exposure to lower than the permissible limits for welding fumes in this present study may justify the disparity of findings between this and the cited study.

A study conducted by Hammond et al., in an automobile factory reported a higher frequency of respiratory symptoms in the spot welders compared to controls; moreover, these symptoms improved greatly in spot welders over the holidays or weekends. Nonetheless, the frequency of COPD and asthma diagnosed by the physicians was not higher in spot welders [13]. In the latter two studies (1999 and 2005), spot welders were exposed to more welding fumes compared to the cases in the present study, perhaps due to the lack of proper ventilation and protective equipment.

Many studies have recently been conducted on other welding techniques and different positive or negative results have been reported by them.

The present findings are inconsistent with the results of studies that found welders experience more pulmonary function disorders compared to controls [8, 10, 25]. The present findings are, however, consistent with the results of studies that found no significant differences between pulmonary function parameters in welders [26-28].

Majority of studies conducted on welders have reported a higher frequency of pulmonary symptoms in welders [10, 12, 28, 29]. In the present study, however, the frequency of respiratory symptoms was very low, and there was no statistical significantly difference between two groups. The present findings were similar to the results obtained by Ould-Kadi F. et al., [30].

In some studies, the number of years served in welding has been reported as an important determinant of pulmonary function disorders [10, 31]. In the present study however, the pulmonary function parameters (except for FEF25-75%) did not correlate significantly with the length of service. Although respiratory symptoms were more frequent in workers who had more work experience in this field, but the difference was not statistically significant due to the low frequency of respiratory symptoms. This finding was similar to the results of Golbabaei F. et al., [12] and Hoffmeyer F. et al., [26] studies.

Pulmonary function parameters and respiratory symptoms did not differ significantly between the smoker and non-smoker spot welders in the present study, which is consistent with the results of the study in gas transmission pipelines welders in Iran, which showed that smoking don't affect pulmonary function parameters in welders before and after work shifts [12]. Some other studies have also shown that smoking and simultaneous exposure to welding fumes do not not correlate with pulmonary function [30, 32]. Nevertheless, some studies have found a synergistic effect for smoking and exposure to welding fumes [6, 33, 34].

Based on some studies, however, smoking may exacerbate the effects of inhaling fumes, even though the present study did not provide enough evidence in this regard. Low frequency and shorter duration of smoking (pack/year) in the spot welders examined in this study may justify this finding, on the other hand, it could be assumed that welders who had more respiratory complaints quit smoking.

The frequency of respiratory symptoms was low in our participants, which may be due to the relatively young population of our study. In a study by Bhumika N. et al., the frequency of respiratory disorders was higher after age 40 and also after 20 years of working in both welding and non-welding groups [25].

In the present study, obstructive pattern was more frequent than the other abnormal patterns in the spot welders, which is consistent with the results of some other studies [24, 25, 29, 35]. In the Rastogi S.K. et al., study, showed that restrictive pattern was more frequent in welders [34]. In studies conducted by Ghahri A., Khadem M. and Golbabaei F, obstructive, restrictive and mixed pulmonary patterns were more frequent in the welders [12]. Luo et al., also observed obstructive and restrictive pulmonary patterns in spot welders [3]. In the study by Erhabor G.E et al., obstructive and restrictive pulmonary patterns were both more frequent in arc-welding workers compared to controls [36].

Mean age and duration of service did not differ significantly between the participants with obstructive patterns and those with restrictive patterns; however, the frequency of smoking in those with obstructive patterns was significantly higher in the control group. Given the higher frequency of obstructive patterns in spot welders, this finding may confirm that pulmonary disorders occur independently of smoking in spot welders and are probably caused by the exposure to spot-welding fumes.

The different results obtained may be due to differences in the frequency of smoking, duration of service, daily working hours, engineering controls such as ventilators in the workplace, workplace isolation and the use of personal protective equipment such as respiratory masks. The type of welding process and work conditions also may differ from one study to another.

One of the strengths of this study was the large sample of spot welders examined. Moreover, mean duration of service was 11 years in this study and all participants had at least five years of work experience in spot welding; the duration of exposure was therefore adequate for causing symptoms and affecting the respiratory function tests. Another strength of this study was the accurate performance of spirometry on the basis of ATS criteria by a physician, which increased the validity of our measurements. Given its cross-sectional design, this study could not differentiate between the effects of current and cumulative exposure. A potential reason for the different results obtained in this study may be due to 'healthy worker effect' both at the time of employment and during work. Workers with a history of respiratory complaints may have not be employed for spot welding or modify or quit their jobs after employment, which results in healthier workers remaining in the job and thus hides the real effect of exposure on the pulmonary function.

The results of this study could not reveal a significant correlation between exposure to spot-welding fumes and reduction in pulmonary function tests or respiratory symptoms. Nonetheless, obstructive pattern was more frequent in spot welders.

Cohort studies are therefore recommended to be conducted in order to evaluate the effects of spot welding on pulmonary function.

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