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Research Article
Respiratory Health Status of Workers that Exposed to Welding Fumes at Lumut Shipyard

Anuar Ithnin, Anas Zubir, Normah Awang and Nur Nabilah Mohamad Sulaiman

Environmental Health and Industrial Safety Programme, School of Diagnostic and Applied Health Sciences, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia

Abstract

Background and Objective: Welding fume exposure has led to the respiratory problems among welders including cough, phlegm, chest illnesses, nausea and fatigue. Inadequate ventilation during welding works causes the situation to worsen. Welding fumes can cause a decrease in lung function among welders. Chronic exposure will lead to other health effects especially COPD (Chronic Obstructive Pulmonary Disease). The objective of this study is to determine the exposure of welding fumes (Cd, Fe, Pb and Zn) towards respiratory health including lung function test (FEV1, FVC, FEV1/FVC, PEFR) of workers in Lumut shipyard, Perak. **Materials and Methods:** This research study the relationship between exposures of welding fumes towards lung function test among workers in Lumut shipyard, Perak. Lung function test was measured by spirometry among 30 welders and 31 non-welders. The concentration welding fume exposure was measured using OSHA ID-121 method. Sociodemographic data, respiratory symptoms and smoking habit data was analyzed based on the ATS 1987 questionnaire. **Results:** The mean concentration for Pb in welding fumes was 2.752 mg m^{-3} which is above 0.5 mg m^{-3} PEL-TWA. The FEV_1 and FVC readings showed significant different between welders and non-welders ($p = 0.001$). Cough and phlegm symptoms showed significant different between welders and non-welders ($p = 0.001$). Welders had higher prevalence in smoking habit than the non-welders. Chest illnesses symptom showed an association with the smoking habit ($p = 0.01$). **Conclusion:** There is relationship between welding fumes exposure on lung function test of workers in Lumut shipyard. Pb in welding fumes has high concentration and exceeded PEL-TWA level. The FEV_1 and FVC in welders are lower than non-welder due to the fumes exposure. Welders showed higher respiratory symptoms than non-welders. Smoking habit is a contributing factor towards respiratory problem.

Key words: Welding fumes, lung function, respiratory symptoms, spirometer, COPD, smoking

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Corresponding Author: Normah Awang, Environmental Health and Industrial Safety Programme, School of Diagnostic and Applied Health Sciences, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia Tel: +60192268912

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Welding is a process to join the metals by heating in suitable temperatures to melt the electrode metal[1]. It is the main process in industries such as construction, mining, petrochemical and shipping. Welding is carried out by melting and merging metal by heating the coated electrode arc between the metal and the work piece. Flux is an electrode outer layer that helps in generating the arc, shielding gas and slag during the welding work is performed[2].

Welding fumes has a very small particle size. It consists of metal oxide particles and gases that could have toxic effects on human health[3]. Welding fumes are a complex mixture of toxic fumes and noxious gases. Metal particles compound in flux may result chemical reactions that could alter the composition of the fumes. The metal particles typically found in welding fumes are Aluminium, Beryllium, Cadmium, Chromium, Copper, Fluoride, Lead, Manganese and Zinc[4].

Welders have higher exposure towards welding fumes. Individuals exposure depend on the location of the welding work being done including on the ship, confined space, workshops or in open areas[5]. Welding fumes in chronic exposure can lead to Chronic Obstructive Pulmonary Disease (COPD). It is a common respiratory disease to the workers that exposed to welding fumes in along period of time. Welding fume particles can cause inflammation and oxidative damage to the respiratory tract. Bronchitis, siderosis and other pulmonary diseases can also occur as a result of exposure to welding fumes[6].

A study by Koh *et al.*[7] in Korean shipbuilding company showed that there is an association between exposure to welding fumes and COPD in welders. Welding fumes believed to cause a decrease in lung function and COPD among welders[7]. A study in Iran on automobile manufacturing company showed the lung function test (FEV_1, FVC) is less among welders than the non-welders group[8].

Since welding workers have the risk of getting many respiratory illness caused by welding fumes, the importance of this study is to give awareness to the workers and for the employer to plan a strategy to ensure safe working environment. This study was conducted to determine the exposure of welding fumes (Cd, Fe, Pb and Zn) towards respiratory health including lung function test (FEV_1, FVC, FEV_1/FVC, PEFR) of workers in Lumut shipyard, Perak.

MATERIALS AND METHODS

Study area: This study is a cross-sectional study that involved workers in Lumut shipyard, Lumut, Perak, Malaysia. This research have been done from September, 2014 until June, 2015. About 30 welders in welding workshop have been selected as an expose group and 31 non-welders as a control group. Total number of respondent is 61.

Socio-demographic background and respiratory symptoms: The questionnaire used was based on the American Thoracic Society[9]. There are three components in the questionnaires, sociodemographic background, respiratory symptoms and smoking habits.

Determination of concentration of welding fumes exposure: Gil Air Plus Personal Air Sampling Pump has been used to determine the concentration levels of welding fume exposure. Mixed Cellulose Esters (MCE) filter paper was used in this measurement. This device was placed in worker's breathing zone while they performing their study. Samples were collected at a maximum flow rate of 2.0 L min^{-1} until reaching a volume of 480-960 L. Then, this MCE filter paper will undergo acid digestion according to OSHA ID-121 method and was analyzed by using Atomic Absorption Spectrometer (AAS). The concentration of Cd, Fe, Pb and Zn in welding fumes were compared with PEL-TWA for air pollutants[10].

Lung function test: Spirometer was used to measure the amount of inspiration and expiration capacity of lung. The spirometry readings (FEV_1, FVC, FEV_1/FVC and PEFR) were measured. The FEV_1 (Forced Expiratory Volume in 1 sec) is the volume of air that the respondent is able to exhale in the 1st sec of forced expiration. The FVC (Forced Vital Capacity) is the total volume of air that the patient can forcibly exhale in one breath. FEV_1/FVC is the ratio of FEV_1 to FVC expressed as a fraction[11]. The PEFR (Peak Expiratory Flow Rate) help to assess the degree of airflow obstruction and subjects. This device has a scale of 60-800 L min^{-1}.

The normal level for spirometry tests are FEV_1 and FVC are 80% above predicted and FEV_1/FVC above 70%. Abnormal levels are divided into obstructive and restrictive. Obstructive pattern will show FEV_1 is less than 80% predicted, FVC is normal or less than the FEV_1 and FEV_1/FVC is less than 70%. Restrictive pattern will show FVC is below 80% predicted FEV_1 is normal or mildly reduced and FEV_1/FVC is above 70%.

Statistical analysis: The values obtained were recorded as mean±SD (Standard Deviation) for statistical evaluation. Data was evaluated using independent t-test to analyze the readings of lung function test and respiratory symptom using SPSS (Statistical Package for Social Studies) Version 20.0 software. Then, Chi-Square test used to analyze the

relationship between respiratory symptom and smoking habit. The $p<0.05$ was taken to be statistically significant with CI (Confidence Interval) of 95%.

RESULTS AND DISCUSSION

Demographic data of welders and non-welders were shown in Table 1 and 2. There was no significant different between this two group in socio-demographic factor. It is important to avoid other factors that can affect the reading of lung function test.

Table 3 showed the concentration of welding fumes exposure. The overall mean concentration for Cd was within the permissible limit by OSHA[10] (0.1 mg m^{-3}). Cadmium was easily found along with Zn and Pb. Cd has been used in the processing industry as an anti-corrosion agent. Exposure of Cd in human body can occur through ingestion, inhalation and dermal contact[12]. High exposure of Cd can cause shortness of breath and damage to the mucous membrane[13]. Moreover, chronic exposure to Cd has been a major problem for kidney damage[14].

For the Fe, the mean concentration for Fe was also within the limit by OSHA[10] (10.0 mg m^{-3}) which was 0.151 mg m^{-3}. Welding materials contained ferrous element. Ferum oxide, Fe_2O_3 is the most abundant constituent resulting from the welding work. Continuous exposure to welding fumes can lead to deposition of iron particles in the lungs[2]. Chronic inhalation of welding fumes containing Fe particles can cause siderosis. This effect was also seen in many iron ore miners and workers[15].

Next, the mean concentration for Pb was 2.752 mg m^{-3} which are above 0.5 mg m^{-3} PEL-TWA by OSHA[10]. The Pb exposure can cause lung cancer, asthma and COPD[16]. According to Khazdair *et al.*[16], the workers that exposed to Pb materials has experienced more respiratory symptoms compared to the unexposed workers. Urine test and serum concentrations of Pb in exposed workers were found to be higher than unexposed workers. These results showed lead exposure affects the respiratory system. Other respiratory symptoms resulting from acute lead exposure are headaches, difficult to breathe and others.

Table 1: Socio-demographic data (N = 61)

Socio-demographic	Welders n (%)	Non-welders n (%)	χ^2	p-value
Gender				
Male	30 (100.0)	31 (100.0)	-	-
Races				
Malay	29 (96.7)	29 (93.5)	0.32	0.57
Non-malay	1 (3.3)	2 (6.5)		
Educational level				
Primary level	29 (96.7)	26 (83.9)	3.06	0.80
Higher level	1 (3.3)	5 (16.1)		
Marital status				
Single	20 (66.7)	19 (61.3)	0.19	0.66
Married status	10 (33.3)	12 (38.7)		

*Significant at $p<0.05$

Table 2: Socio-demographic data (N = 61)

Socio-demographic	Welders (Mean±SD)	Non-welders (Mean±SD)	t-value	p-value
Age	27.40±9.550	29.40±8.910	-0.84	0.40
Height (cm)	1.69±0.050	1.69±0.060	-0.42	0.68
Weight (kg)	67.30±14.68	70.40±13.89	-0.84	0.40
BMI	23.60±4.880	24.40±3.720	-0.72	0.48
Years worked	4.67±5.680	6.94±7.390	-1.34	0.19

*Significant at $p<0.05$

Table 3: Welding fume concentration

Parameters	Minimum (mg m^{-3})	Maximum (mg m^{-3})	Mean (mg m^{-3})	SD
Cd	0	0.029	0.007	0.008
Fe	0	1.09	0.151	0.265
Pb	0	8.032	2.752	2.832
Zn	0	0.02	0.006	0.007

*Significant at $p<0.05$

Table 4: Lung function test between welders and non-welders

Parameters	N	Welders (Mean±SD)	n	Non-welders (Mean±SD)	t-value	p-value
FEV_1	30	83.47±5.67	31	89.68±6.62	-3.93	0.001*
FVC	30	84.47±13.95	31	93.61±8.68	-3.09	0.001*
FEV_1/FVC	30	94.97±12.48	31	95.03±7.40	-0.02	0.98
PEFR	30	486.00±100.40	31	496.77±69.68	-0.49	0.63

Table 5: Prevalence of respiratory symptoms in welders and non-welders

Symptoms	Welders n (%)	Non-welders n (%)	χ^2	p-value
Cough			3.79	0.05*
Yes	7 (23.3)	1 (3.2)		
No	23 (76.7)	30 (96.8)		
Phlegm				
Yes	14 (46.7)	3 (9.7)	8.62	0.001*
No	16 (53.3)	28 (90.3)		
Wheezing				
Yes	4 (13.3)	2 (6.5)	0.22	0.64
No	26 (86.7)	29 (93.5)		
Chest Illnesses				
Yes	4 (13.3)	2 (6.5)	0.22	0.64
No	26 (86.7)	29 (93.5)		

*Significant at p<0.05

Furthermore, in this study, the mean value for Zn was 0.006 mg m^{-3} which was below 5.0 mg m^{-3} PEL-TWA by OSHA[10]. Metal fume fever can be resulted to the effect of Zn exposure through inhalation. This acute syndrome mostly occurred through inhalation of fumes particle size less than 1 µm. The workers started to recover a few hours after exposure. Other symptoms were fever, muscle pain, lethargy, chest pain and coughing[17].

From the statistical analysis of the data, there was a significant different between welders and non-welders in FEV_1 and FVC readings. However, FEV_1/FVC and PEFR showed no significant different between welders and non-welders. The FEV_1, FVC, FEV_1/FVC and PEFR readings is lower in welders compared to non-welders. This can be support from the research done by Sharifian *et al.*[1] that showed the association between effect of welding fume towards lung function of welders. According to Sharifian *et al.*[1], welders with exposure longer than 5 years showed lower in FEV_1 and FEV_1/FVC. The fume particulates from weld activity may cause inflammation and oxidative damage to the airways and also lead to COPD[6].

Based on independent t-test, cough and phlegm symptoms showed significant different between welders and non-welders (Table 5) while wheezing and chest illnesses symptoms showed no significant different between both group. For cough and phlegm, welder seemed to have higher symptom non-welders. Many research have showed a higher prevalence of respiratory symptoms in welders due to the accumulation of welding particles in respiratory tract which will increase mucus[1].

Table 6: Smoking habit between welders and non-welders

Smoking habit	Welders n (%)	Non-welders n (%)	p-value
Smoking			
Yes	21 (70.0)	7 (22.6)	0.001*
No	9 (30.0)	24 (77.4)	

*Significant at p<0.05

Table 7: Relationship between respiratory symptoms and smoking habit

	Smoking habit	
Respiratory symptoms	χ^2	p-value
Cough	0.23	0.63
Phlegm	0.40	0.53
Wheezing	0.63	0.43
Chest Illness	15.45	0.01*

*Significant at p<0.05

As shown in Table 6, there was a significant different of the smoking habit between welders and non-welders. Welders have higher prevalence in smoking habit than the non-welders. Table 7 showed an association between the smoking habits with respiratory symptoms. From the Chi-square test, there was an association between chest illnesses symptom and smoking habit. This result can be supported by the research from Kakoee[8] that stated most welders with respiratory symptoms were a smoker and consumed tobacco. Based on a study[18], there is a synergistic relationship between the smoking habit and welding fume exposure with lung disease. It also increased the respiratory symptoms among workers. Negative effects of the lung function were related to the smoking habit[19]. From the previous study[20], smokers seemed to have highest risk for respiratory symptoms and lung function loss.

CONCLUSION

In a conclusion, there is relationship between welding fumes exposure on lung function test of workers in Lumut shipyard. Pb in welding fumes has high concentration and exceeded PEL-TWA level. The FEV_1 and FVC in welders are lower than non-welder due to the fumes exposure. Welders show higher respiratory symptoms than non-welders. Besides, smoking habit was also one of a contributing factor towards respiratory problem.

SIGNIFICANCE STATEMENT

Most of the previous study only focus on the respiratory symptoms and spirometry test to the welders, while this study comprises of the lung function test, the respiratory symptoms and also monitoring the individuals exposure to the welding fumes which were Cd, Fe, Pb and Zn. From this study, it could determine whether the exposure to these heavy metals within limits or not. The exposure to the Pb was above the permissible limit. The results have been submitted to the administration of the industry to take proper control measure such as elimination, substitution or engineering control in order to minimize the exposure. Besides, this study differ from other study as this study has been done at the shipyard industry which the exposure and concentration of heavy metals would be different in each industry.

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