# Exposure to $PM_{10}$ and Lung Function Among Welders of Metal Working Factory in Selangor

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**ABSTRACT:** Welding is one of the key components of numerous metal-working industries, and its fume has potential physical and chemical health hazards. Several evidences from previous scientific studies have shown that welding fumes contain particles to which the exposure can affect lung function of the welders. The aim of this study is to determine the personal exposure to $PM_{10}$ and lung functions, as well as respiratory symptoms among welders of a metal working factory with office workers as the comparative group. This study involved 33 welders and 43 office workers. Purposive sampling method was used to recruit respondents, and those who fulfilled the inclusion criteria were selected. A set of questionnaire adopted from American Thoracic Society was used to collect information on socio-demographic data and respiratory symptoms. Personal exposure to $PM_{10}$ was measured using portable air sampling pump GilAir-5 (Sensidyn, U.S.A) and lung function test was performed using spirometer Chestgraph HI-101 (Chest M.I Inc., Tokyo). The exposure of $PM_{10}$ for the welders were 4 times higher (471.6 $\mu g/m^3$ (343.9)) as compared to the non-exposed group (121.1 $\mu g/m^3$ (6.3)). There were significant differences in FVC (litre) ($p = 0.03$), $FEV_1$ (litre) ($p = 0.02$), FVC% ($p = 0.02$) and $FEV_1$% ($p < 0.001$) between the welders and the non-exposed group. The numbers of reported respiratory symptoms were significantly higher among welders and logistic regression showed that exposure to $PM_{10}$ increased the risk of chronic cough. The welding fume was found to be a factor contributing to significant risk of chronic cough, chronic phlegm and chest tightness after adjusted for smoking status. It is suggested that welders are highly exposed to $PM_{10}$ compared to non-exposed, and there is an increased risk of exposure to their respiratory health.

**Keywords:** $PM_{10}$, lung function test, respiratory symptoms, welders

## Introduction

Rapid industrialisation has resulted in an increase of metal industry in Malaysia especially in metal manufacturing and working industry. The welding processes are the major task of production activities in this industry. Welders are the workers who are involved in welding processes at work. About 800,000 welders are employed full-time worldwide to perform welding as their work duties (Han *et al.,* 2005). Welding is the process in which metal or other thermoplastic materials are joined together by the application of heat or pressure, or both with or without the use of a filler metal. The heat vaporises a small quantity of metals and releases welding fumes into the air, which can adversely affect the health of the welders as well as the health of those in the immediate area (Rice *et al.,* 2011). Welding fume exposure in the workplace is a serious occupational hazard as welding produces the complex mixture of fumes, particles and gases.

Particles from welding processes are the sources of fine and ultrafine particles. Depends on the components and materials used in the processes, this particles are enriched in metals (Isaxon *et al*., 2009). Most of the particles in welding fumes are less than 1μm in diameter when they are produced, but they appear to grow in size with time due to agglomeration. The adverse effects of particulates on human health have been recognised for a long time. Inhalation of these particles can cause inflammatory reactions in the lung, and a long period of exposure can interfere with the lung function. There are evidences to show the decline of lung function on those engaging in welding fumes for 10 years (Antonini *et al.*, 2003, Panjwani, 1992). However, the degree of the risk to welder's health from fume exposure depends on the welding fume composition and concentration as well as the length of exposure to the fume (Balkhyour and Goknil, 2010).

The welding process emits almost 25% of aerodynamic particles with diameter between 0.4-0.7μm in average. There is evidence showing that indoor welding will increase the emission ($PM_{10}$) due to closed space, while the concentration of $PM_{2.5}$ is the lowest in outdoor space. Most of the medium

metal manufacturing factories are operating in open air and are not equipped with local exhaust ventilation. This study aimed to evaluate the lung function of welders and their personal exposure to $PM_{10}$ released from welding activity at a metal manufacturing factory. Findings of this study are important to determine the relationship between lung function parameters and personal exposure to $PM_{10}$ generated from scientific data analysis.

## Methodology

### *Study location*

This study was carried out at a metal working factory located in Seri Kembangan, Selangor. This company provides services on metal fabrication and installation of metal gates, floors, roofs and doors. There were 64 workers in the company, involving in various activities as welders, machine operators, painters and forklift drivers. All the workers were present at the workplace from 8.30 a.m until 6 p.m for 6 days in a week. Permission was obtained from the General Manager of the company before the study was carried out.

### *Study design*

A cross-sectional comparative study design was used in which the pollutants exposure and health effects were measured at the same time while comparing between welders and non-exposed group. Final recruited respondents comprised 33 male welders from a metal working factory and 43 male administrative staff from various departments of Veterinary Faculty, Universiti Putra Malaysia, Serdang.

### *Sampling*

The respondents were recruited by purposive sampling method. They were selected based on the inclusion criteria provided such as male, age range between 18 to 45 years, no past history of chronic lung disease and kidney failure, and at least 1 year working experience on the current job

task. The inclusion criteria were applied for both study groups. The study purposes were explained well to respondents and permission was obtained prior to participating in this study.

## Materials and Data Collection

### *Questionnaire*

A standardised set of questionnaire, ATS-DLD-78 adopted from American Thoracic Society (Ferris, 1978) was used to obtain the information on the respondents' background and respiratory symptoms. This was a self-administered questionnaire presented in Malay language.

### *Personal air monitoring*

Personal $PM_{10}$ concentrations were collected for 8 hours by using a personal air sampling pump that was installed at the breathing zone of welders, defining as area approximately 20-30 cm from the nose and the mouth. The sampling equipment included a mixed cellulose ester (MCE) filter, with 0.8 microns pore size and 37 mm diameter, attached to the 37 mm open face cassette and cyclone. This sampling pump was based on the gravimetric principle and was operated at a flow rate of 1.7 L/min according to NIOSH method 0600.

### *Lung function test*

Lung function of the respondents was measured by using the spirometer Chestgraph HI-101 before the start of working hours (early in the morning). This test was used to measure parameters which were the forced expiratory volume in 1 second ($FEV_1$) and the forced vital capacity (FVC). These parameters evaluated the lung function of the respondents. The evaluation of spirometric test was conducted by using standard procedures of American Thoracic Society (American Thoracic Society, 1991) and the predicted normal value of lung function was based on a study by Singh ***et.al.*** (1993). Prior to the lung function measurement, respondents' body

weight and height were measured using the SECA electronic weighing scale and body meter model 206, respectively.

*Statistical analysis*

Frequency distribution was generated for the socio-demographic data and the respondents' smoking status. Comparison between groups for parameters of respiratory symptoms, lung function and concentration of $PM_{10}$ were tested with Mann-Whitney U test for continuous data, while Chi-square ($\chi^2$) test with risk estimate was performed for categorical variables. The correlation between concentration of $PM_{10}$ and lung function parameters were tested using Spearman correlation. The non-parametric tests were used since the data were not normally distributed. Logistic regression was performed, where odds ratios and 95% confidence intervals (CI) were estimated by examining the occurrence of respiratory symptom and taking into account several potential risk factors such as $PM_{10}$ concentration, exposure group and smoking. Data were analysed by using Statistical Packages for Social Sciences (SPSS, version 20). All statistical tests were two sided; a p value of 0.05 or less was adopted for statistical significance.

*Study ethics*

Ethical clearance was obtained from the Ethical Committee of Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. The management of the company and the respondents were briefed about the study and written consents were obtained from the respondents.

## Results

*Socio-demographic data, working duration and smoking status of respondents*

Two comparative groups were involved in this study with 33 male welders and 43 office staff, representing the exposed and the non-exposed groups, respectively. Result shown in **Table 1** contains information on the distribution of socio-demographic status such as race, education

level, age, height, weight, work duration data and smoking status of respondents. A significant difference was obtained for ethnicity and education level which shows that respondents were from various ethnicity and education levels. The statistical results obtained for other socio demographic data and working duration show that there was no significant difference tested between these two groups of respondents.

*Concentrations of $PM_{10}$ exposure*

The data analysis shows that the welders were exposed to an almost 4 times higher concentration of $PM_{10}$ as compared to the non-exposed group. The non-parametric test was carried out as the data were not normally distributed. The median (IQR) values are shown in **Table 1,** where the welders were stated to expose to 471.6±343.9 μg/$m^3$ of $PM_{10}$ compared to only 121.1± 6.3μg/$m^3$ for the non-exposed group. The Mann-Whitney U test shows a significant difference ($p<0.001$) in the concentration levels ranged from 122.3 to 863.0μg/m3 and 87.9-121.8μg/m3 for the welders and the non-exposed group, respectively.

**Table 1**: Comparison of socio-demographic data, work data and $PM_{10}$ concentrations between two comparative groups

| **Variable** | **Welders (n=33) Number (%)** | **Non-exposed (n=43) Number (%)** | **p-value** |
|---|---|---|---|
| **Race** | 18 (54.4) | 37 (86) | <0.001 |
| Malay | 9 (27.3) | - | |
| Chinese | - | 6 (14) | |
| Indian | 6 (18.2) | - | |
| Others | | | |
| **Education** | | | |
| PMR | 7(21.2) | 1(2.2) | <0.001 |
| SPM | 12(36.4) | 16 (35.6) | |
| STPM/Diploma | - | 18 (40) | |
| Others | 14(42.4) | 8(18.6) | |
| **Age (years)** | 31(14) | 31(11) | 0.753 |
| **Weight (kg)** | 64(13) | 62(16) | 0.858 |
| **Height (m)** | 1.67(0.07) | 1.65(0.10) | 0.098 |
| **Smoking status** | | | |
| Smokers | 12(36.4) | 13(30.2) | 0.573 |

| | | | |
|---|---|---|---|
| Non-smokers | 21(63.6) | 30(69.8) | |
| **Work duration** | | | |
| (years) | 5(5) | 4 (6) | 0.924 |
| **$PM_{10}$** | 471.6 | 121.1 | <0.001* |
| ($\mu g/m^3$) | (343.9) | (6.3) | |

N=76, *significance level at p<0.05

*Association of respiratory symptoms between the welders and the non-exposed groups*

The respiratory symptoms among the respondents were determined through questionnaires adopted from American Thoracic Society (ATS) (Ferris, 1978). The Chi-square ($\chi^2$) test shows several symptoms such as chronic cough, phlegm and chest tightness were significantly (p<0.05) higher reported among the welders compared to the non-exposed group (**Table 2**). Meanwhile, the logistic regression analysis shows a 2 times higher risk of reported chronic cough after adjusted for smoking factor among welders. Logistic regression was performed to determine the main factor contributing to chronic chough, chronic phlegm and chest tightness of respondents.

**Table 2**: Logistic regression of respiratory symptoms before and after adjusted for smoking status

| **Independent variable** | **Welders (n=33)** | **Non-exposed (n=43)** | **Crude OR (CI 95%)** | **Adjusted OR (CI 95%)** | **p-value** |
|---|---|---|---|---|---|
| Chronic cough | 11(33.3) | 3(7.0) | 6.67 (1.68-26.46) | 12.57 (3.07-51.4) | 0.003* |
| Chronic phlegm | 19(57.6) | 4(9.3) | 13.23 (3.83-45.69) | 3.40 (1.20-9.40) | <0.001* |
| Chest tightness | 12(36.4) | 1(2.3) | 24.0 (2.92-197.2) | 2.00 (0.59-6.70) | <0.001* |
| Wheezing | 0 | 2(4.4) | - | - | 0.50# |

*significance level at p<0.05, OR significant >1 #Fisher's Exact Test

*Lung functions of welders and non-exposed group*

The Mann-Whitney U test shows a significant difference for FVC (litre), $FEV_1$ (litre), FVC%, $FEV_1$% and $FEV_1$/FVC% in comparison between the welders and the non-exposed groups (**Table 3**). The median (IQR) values for the lung function parameters were lower among the welders as compared to the non-exposed group. The lung function abnormalities were determined by categorising the significant values obtained according to the range stated by ATS (American Thoracic Society, 1991) of lung abnormality (**Table 4**). For the abnormalities of lung function the Chi-square test with risk estimate (OR) was used and result showed that only $FEV_1$% (OR=2.95, 95% CI= 1.11-7.9) have a significant risk ($p<0.001$) when compared between the welders and non-exposed group. Spearman Rho's test shows an insignificant relationship for the exposure to $PM_{10}$ with lung functions parameters among the non-exposed group (**Table 5**).

**Table 3**: Comparison of lung function between two comparative groups

| | **Welders (n=33)** | | | **Non-exposed(n=43)** | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | **Median (IQR)** | **Range** | **Mean Rank** | **Median (IQR)** | **Range** | **Mean Rank** | **z-value** | **p-value** |
| FVC (litre) | 2.98(0.25) | 1.88-3.29 | 30.1 | 3.10(0.29) | 2.63-4.15 | 45.0 | -2.93 | 0.03* |
| $FEV_1$ (litre) | 2.78(0.69) | 1.63-3.12 | 30.0 | 2.93(0.46) | 1.76-3.28 | 45.4 | -3.10 | 0.02* |
| FVC% | 81.4(21.0) | 58.1-97.4 | 29.4 | 89.5(18.3) | 57.8-113-1 | 45.5 | -3.15 | 0.02* |
| $FEV_1$% | 80.8(19.5) | 56.1-103.3 | 27.5 | 87.9(18.6) | 51.9-105.7 | 47.0 | -3.81 | <0.001* |
| %$FEV_1$ /FVC | 99.6(11.6) | 74.0-112.8 | 35.7 | 102.1(9.7) | 90.8-137.2 | 40.1 | -0.97 | 0.332 |

* Significance level at $p<0.05$

**Table 4**: Comparison of lung function abnormalities between two comparative groups

| Variables | | Welders (n=33) | Non-exposed (n=43) | | | |
|---|---|---|---|---|---|---|
| | | Number (%) | Number (%) | Odds Ratio | 95% CI | p-value |
| FVC% | Abnormal | 14(42.4) | 10(23.3) | 0.41 | 0.153-1.105 | 0.075 |
| | Normal | 19(57.6) | 33(76.7) | | | |
| $FEV_1$% | Abnormal | 16(48.5) | 6(14.0) | 2.95 | 1.105-7.889 | 0.001* |
| | Normal | 17(51.5) | 37(86.0) | | | |

* Significance level at p<0.05

**Table 5**: Association between lung function and concentrations of $PM_{10}$ measured

| $PM_{10}$ concentrations ($\mu g/m^3$) | Welders (n=33) | | Non-exposed (n=43) | |
|---|---|---|---|---|
| | r-value | p-value | r-value | p-value |
| FVC ( litre) | 0.74 | 0.68 | 0.26 | <0.00* |
| $FEV_1$ ( litre) | -0.14 | 0.44 | 0.13 | <0.00* |
| FVC% | -0.12 | 0.52 | 0.30 | <0.00* |
| $FEV_1$% | -0.29 | 0.10 | 0.21 | <0.00* |
| % $FEV_1$ /FVC | -0.20 | 0.27 | -0.31 | 0.06 |

*significance level at p<0.05

## Discussion

*Study background, socio-demographic data and physical status*

This study involved an exposed group of 33 welders of metal gas (oxygen) arc welding. They were dealt with welding activities for at least 46 hours a week in an open space area without wearing respiratory protective devices. The recruited welders fulfilled the inclusion criteria such as male, age range between 18 to 45 years, no past history of chronic lung disease and kidney failure, and at least 1 year working experience in this field. Meanwhile, the non-exposed group was represented by 43 office staff, which were chosen from the same inclusion and exclusion criteria with the exposed group. Respondents for both groups were matched for age, height,

weight and duration of employment (**Table 1**). Several ethnicities and various education levels were involved in this study.

The comparison of $PM_{10}$ concentration exposure between the welders and the non-exposed group confirmed that the welders were exposed to 4 times higher concentration of $PM_{10}$ as compared to the non-exposed group. This was expected as welders dealt with welding fumes that contained dust, and the exposure had adverse respiratory health effect (Haluza *et al.*, 2014). A previous study conducted among 70 welders of shipyard by Nurul (2007) showed the mean value of $PM_{10}$ recorded for the welders (1793± 3289μg/$m^3$) as 35 times higher compared to the mean value of the comparative group (50.53± 11.32 μg/$m^3$).

The respiratory symptoms observed in this study such as chronic cough, chronic phlegm, chest tightness, and wheezing were based on the answers filled in the questionnaire. Among these symptoms, welders showed a higher prevalence of 24 times for chest tightness (OR=24, 95% CI = 2.92-197.2) followed by 13 times for chronic phlegm (OR=13.23, 95% CI = 3.83-45.7) and 7 times for chronic cough (O.R = 6.67, 95% CI 1.68-26.5, p = 0.003) in comparison to the comparative group. Welders experienced the symptoms more as they were more exposed to the welding fumes compared to workers who had never welded. Besides that, previous study by Ozdemir (1995) on a 110 of manual arc welders exposed primarily to mild steel welding showed the respiratory symptoms were more prevalent among confined-space welders. Meanwhile, Beckett *et al.* (1996) also found that welders were reported to have an increased of self-reported respiratory symptoms. As revealed by logistic regression, smoking increases the risk of having chronic cough 2 times higher for the welders exposed to welding fume ($PM_{10}$). A study by Haluza *et al*. (2014) showed the impact of smoking and an increased risk of respiratory impairment among the welders.

All the lung function parameters show significant correlations and reductions for the non-exposed group compared to the welders by having a *p* value less than 0.05 ($p<0.05$). In comparison by a previous study done among 137 spot welders in an automobile assembly, the significant reduction values were only found for $FEV_1$ and $FEV_1$/FVC% (Loukzadeh *et al.,*

2009). In a cross-sectional study of a small population of welders (n = 46), Wang et al. (1994) found that these welders had normal lung functions compared with a reference group of vehicle assembly workers who had never welded. Meanwhile, result from the Spearman Rho's test found that there were insignificant inverse correlation between exposure to $PM_{10}$ concentrations and lung function among welders. Moreover, the air pollutant effects can be influenced by many factors such as level of exposure, individual susceptibility, age, duration of exposure, health status and smoking habit (World Health Organization, 2000).

## Conclusion

This study suggested that there is a reduction in lung function and an increased risk of reported respiratory symptoms such as chronic cough, chronic phlegm and chest tightness among the welders. This was shown firstly, the occupational exposure to elevated concentrations levels to $PM_{10}$ in welding fume through the significant difference showed in chronic cough, chronic phlegm and chest tightness symptom of respiratory among the welders compared to the office workers (non-exposed group). Secondly, the lung function test showed the reduction of FVC, $FEV_1$ measured (litre) and FVC, $FEV_1$ (%) for the welders compared to the comparative group. However, in this study, welders who were exposed to $PM_{10}$ showed no insignificant association with lung function parameters. This study cannot be generalised to a population as it involved certain criteria of respondents. Further and longitudinal studies are needed to confirm the main causal factors of increased reported respiratory symptoms and reduced lung function of the welders.

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