Lung Functions of Welders in Three Automotive Related Industries in Malaysia

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***Abstract*—Lung functions of 30 welders in Plant 1, 53 welders in Plant 2 and 44 welders in Plant 3 of automotive industries in Selangor and Pahang, Malaysia were investigated. Lung functions of 52 non-welders subjects working in the similar industries were also investigated. Lung function test by using handheld spirometer were conducted for welders and non-welders. Metal fumes samples collected from the breathing zone of the welders were analyzed by inductively coupled plasma mass spectroscopy (ICP-MS). None of the metal elements concentration was exceeding the permissible exposure limit (PEL) for all plants. In addition, statistical analysis showed significant mean difference of lung functions between welders and non-welders. Welders in Plant 2 suffered the most on decreased values of lung functions. The results of this study strongly suggest proves of significant respiratory health risk despite the measurement of the welding fumes exposure was still within the Malaysian allowable guidelines range.**

***Index Terms*—lung function effects, Malaysia, welders, welding fumes**

I. Introduction

Hundreds of millions of people throughout the world are working under circumstances that foster ill health or unsafe. It is estimated that yearly over two million people worldwide die of occupational injuries and work-related diseases. In fact more people die from diseases caused by work than are killed in industrial accidents [1]. Malaysia is a developing nation and the manufacturing sector is the major contributor to the Malaysian economy with the number of 1,693,154 person engaged in manufacturing sector in 2009 [2]. One of the main processes in manufacturing sector is welding. According to AWS and EWI (2000) [3], welding will continue to be the preferred method of joining for world class product until 2020.

Welding is a common industrial process in manufacturing sector that has both acute and long term chronic hazards mainly from the inhalable welding fumes. Welding exposure differs from variation of industrial setting, types of ventilation, type of welding processes and materials used [4].

In Malaysia, Under the Occupational Safety and Health Act 1994, Use and Standards of Exposure of Chemical Hazardous to Health regulation (USECHH), chemical classified hazardous to health with its permissible emission limits (PEL) were listed and need to be comply by the employer [5]. Recently, literatures has emerged and offers contradictory findings about proves of significant health risk despite the measurement of airborne welding exposure was still under the permissible guidelines range [6]-[8].

II. Related Researches

Previous studies had been conducted in evaluating the effect of chemical exposure to the lung function of welders. Studies have shown reduction of lung function value in welders' population compared to control group [9]-[11]. Welders were commonly associated for restrictive disorder due to welding exposure [12]-[14]. On the other hand, tobacco smoking was commonly associated with obstructive disorder [15], [16]. In addition, research on tobacco smoking welders suggest synergistic relation between the effects of smoking and welding causing lung disease and increased respiratory symptom [17]-[19].

In Malaysia, only limited study had been done on this matter. Thus, this study was conducted to assess the welding fumes concentration and lung function status of investigated welders by taking into consideration the welder's duration of smoking, duration of exposure and welding job process.

It is expected that a better understanding of welding exposure in Malaysia automotive industry will be obtained in order to promote the protection through legislation, health communications strategies or behavioral intervention where such data are needed.

Manuscript received November 23, 2013; revised May 5, 2014.

III. Methodology

A. Study Population

The investigation was conducted in three automotive related industries involving welding job process of spot gun, spot weld and robotic weld. Plant 1 consists of 30 male welders, Plant 2 consists of 53 male welders and Plant 3 consists of 44 welders. Plant 1 had the average of 8 hour working shifts, Plant 2 has 12 hours average working shifts and Plant 3 has 14 hours average working shifts. 53 non-welder male workers that did not have continuous exposure to welding fumes were selected from similar workplaces as control. They were primarily of technicians, engineers and administrators. All welders worked without the benefit of fume ventilation or proper respiratory protective devices.

B. Welding Fumes Personal Sampling

Sampling heads were located within the breathing zone of the welders. At least one employee in ten were sampled in a properly selected homogeneous group performing similar tasks [20]. Personal sampling of welding fumes was done with the objective to get exposure on maximum risk workers. Thus, in situation where more than one samples were obtained, the results with the highest concentration in most of the elements were selected. The filters media (mixed cellulose ester 0.8 μm pore sizes) were analyzed by using ICP-MS with microwave digestion method for sample analysis according to ASTM D7439-08 method [21]. Samples were delivered to the accredited laboratory for analysis of 15 metal elements (aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, ferum, lead, manganese, molybdenum, nickel, silver and tin). The concentrations were calculated in time weighted average 8 hours (TWA 8).

C. Lung Function

Lung Function Tests (LFTs) were performed on handheld spirometer (Micro Medical DL, UK) connected to spirometer software (Care Fusion, San Diego) on a notebook computer. Spirometer was calibrated daily with a 3L calibration syringe. Interviews were conducted before conducting maneuvers to record demographic data, smoking habit and working experience. The maneuver was explained with the help of short video clip demonstration. Tests were conducted according to forced vital capacity procedure of the American Thoracic Society recommends [22]. Measured parameters were forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), peak expiratory flow (PEF) and FEV_1/FVC ratio (expressed as a percentage of the predicted value unit). The predicted set used in this study was taken from Pneumobile Project, Indonesia [23]. Interpretation and derivation of the value of normal, obstruction and restriction lung function result were done according to the American Thoracic Society (ATS) [22].

D. Statistical Analysis

Statistical analysis was conducted by SPSS software version 18 (SPSS Inc., Chicago). Analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) was used to compare mean lung function parameters between welders and control groups. Pearson correlation analysis was done to get association between working duration, smoking duration and type of welding with lung function. Further analysis using multiple regressions analysis was done to confirm the predictors of the lung functions increased/decreased value. The level of significance was taken as $p < 0.05$.

IV. Results and Discussion

The personal welding fumes exposures for Plant 1, Plant 2 and Plant 3 according to welding job process were tabulated in Table I, Table II and Table III respectively.

TABLE I. Personal Sampling Welding Fumes Concentration for Plant 1

Elements	Spot gun (mg/m³)	Spot gun +sealant (mg/m³)	USECCH PEL (mg/m³)
Aluminum	0.018	0.02	5.0 (resp.) 15.0(total)
Antimony	< 0.001	< 0.001	0.5
Arsenic	0.002	0.003	0.010
Beryllium	< 0.001	< 0.001	0.002 C 0.005
Cadmium	< 0.001	< 0.001	0.005
Chromium	0.009	0.011	0.5
Cobalt	< 0.001	< 0.001	0.1
Copper	0.003	0.002	1.0
Iron	0.633	0.027	10
Lead	< 0.001	0.001	0.05
Manganese	0.006	n/d	C5
Molybdenum	< 0.001	< 0.001	5.0(soluble) 15(total insoluble)
Nickel	n/d	n/d	1.0
Silver	0.001	n/d	0.01
Tin	n/d	n/d	2.0

<: less than, n/d: not detected

TABLE II. Personal Sampling Welding Fumes Concentration for Plant 2

Elements	Spot gun (mg/m³)	Spot weld (mg/m³)	Robotic weld (mg/m³)	USECCH PEL (mg/m³)
Aluminum	0.021	0.014	0.021	5.0 (resp.) 15.0 (total)
Antimony	< 0.001	< 0.001	< 0.001	0.5
Arsenic	0.003	0.003	0.003	0.010
Beryllium	<0.001	< 0.001	< 0.001	0.002 C 0.005
Cadmium	<0.001	< 0.001	< 0.001	0.005
Chromium	0.009	0.007	0.007	0.5
Cobalt	<0.001	n/d	< 0.001	0.1
Copper	0.003	0.002	< 0.001	1.0
Iron	0.019	0.008	0.362	10
Lead	0.001	0.001	0.002	0.05
Manganese	0.009	0.012	0.082	C5
Molybdenum	<0.001	< 0.001	< 0.001	5.0(soluble) 15(total insoluble)
Nickel	n/d	n/d	n/d	1.0
Silver	<0.001	< 0.001	0.001	0.01
Tin	<0.001	n/d	< 0.001	2.0

<: less than, n/d: not detected

TABLE III. PERSONAL SAMPLING WELDING FUMES CONCENTRATION FOR PLANT 3

Elements	Spot gun (mg/m^3)	Spot weld (mg/m^3)	Robotic weld (mg/m^3)	USECCH PEL (mg/m^3)
Aluminum	0.038	0.021	0.028	5.0 (resp.) 15.0(total)
Antimony	n/d	n/d	n/d	0.5
Arsenic	0.009	0.008	0.009	0.010
Beryllium	< 0.001	< 0.001	n/d	0.002 C 0.005
Cadmium	n/d	< 0.001	n/d	0.005
Chromium	0.028	0.028	0.034	0.5
Cobalt	n/d	n/d	n/d	0.1
Copper	0.003	0.002	0.005	1.0
Iron	0.602	0.053	0.265	10
Lead	0.001	0.001	0.001	0.05
Manganese	0.012	< 0.001	0.031	C5
Molybdenum	n/d	n/d	n/d	5.0(soluble) 15(total insoluble)
Nickel	n/d	n/d	n/d	1.0
Silver	n/d	n/d	< 0.001	0.01
Tin	n/d	n/d	< 0.001	2.0

<: less than, n/d: not detected

There were no metal elements that exceeding USECCH PEL for all plants. Iron was the highest elements concentration in all plants with 0.633 (mg/m^3) detected in spot gun welding job process in Plant 1. Several elements such as antimony, beryllium, cadmium, cobalt, molybdenum, nickel and tin were detected below the limit of detection on all plants.

Lung function data (mean ±standard deviation (SD)) of welders on each plant and control groups was shown in Table IV. Apparently lung function results showed that the mean of all lung function parameters of Plant 1, Plant 2 and Plant 3 were lower than control group. The multivariate MANOVA analysis reveal there was a significant mean difference of lung function values between groups $F(12,512)=3.84$, $p < .01$. Further separate univariate ANOVAs on the outcome variable reveals welders on each plant had significant difference of mean value of FEV1/FVC, $F(3,175)=2.70$, $p < .05$ and PEF, $F(3,175)=12.70$, $p < .01$ compared to control group.

TABLE IV. MEAN VALUES OF LUNG FUNCTIONS FOR CONTROL, PLANT 1, PLANT 2 AND PLANT 3

Criteria	Control n=52 (mean ±SD)	Plant 1 n=30 (mean ±SD)	Plant 2 n=53 (mean ±SD)	Plant 3 n=44 (mean ±SD)
Age	34.56 ±7.65	29.73 ±9.04	30.62 ±5.96	28.84 ±5.55
FVC (% pred)	88.33 ±12.19	87.20 ±12.90	84.09 ±15.79	87.86 ±13.20
FEV_1 (% pred)	94.58 ±12.40	90.83 ±11.48	88.51 ±15.30	91.14 ±12.99
FEV_1/ FVC	107.94 ±6.38	104.87 ±7.82	105.91 ±9.89	103.61 ±5.55
PEF (% pred)	84.67 ±11.93	79.53 ±15.64	68.58 ±16.07	71.68 ±14.50

TABLE V. PEARSON CORRELATION BETWEEN LUNG FUNCTION OF WELDERS IN EACH PLANT WITH WORKING YEARS, SMOKING YEARS AND TYPE OF WELDING.

Plant 1				
	FVC	**FEV1**	**FEV1/FVC**	**PEF**
Number of working years	-.193	-.023	.352	-.180
Number of smoking years	-.294	-.051	.579**	-.125
Type of welding	-.108	-.330	-.247	-.073
Plant 2				
	FVC	**FEV1**	**FEV1/FVC**	**PEF**
Number of working years	-.404**	-.399**	.131	-.024
Number of smoking years	.015	-.056	-.056	-.132
Type of welding	.056	.200	.149	.092
Plant 3				
	FVC	**FEV1**	**FEV1/FVC**	**PEF**
Number of working years	.021	.146	.306*	.016
Number of smoking years	.093	.072	-.037	-.202
Type of welding	.114	.077	-.098	.101

*p<.05, **p<0.01

Table V shows the correlation between lung functions of welders in each plant with working years, smoking years and type of welding. Pearson correlation reveals there was significant relationship in each plant as follow;

Plant 1: significant relationship between FEV1/FVC and number of smoking years(r= .58, p (two tailed) < .001)

Plant 2: significant relationship between FVC and number of working years (r= -.40, p (two tailed) < .001). Significant relationship between FEV1 and number of working years (r= -.40, p (two tailed) < .001)

Plant 3: significant relationship between FEV1/FVC and number of working years (r= .31, p (two tailed) < .05)

Further analysis was done with multiple regression analysis, and the results for each plant were as follows;

Plant 1: Further analysis by multiple regressions (backward stepwise method) confirmed number of smoking years was the significant predictor to the increase values of FEV1/FVC. However, working duration and type of welding were not the significant predictors of FEV1/FVC. Apparently high values FEV1/FVC relates with restrictive disorder which contradicts with smoking effects which was the low values of FEV1/FVC (obstruction disorder). To clarify these issues, analysis between smoker and non smoker welder were carried out. Thus multiple regressions analysis (backward stepwise method) were conducted again for FEV1/FVC value as dependent variables, smoking status (smoker and non smoker) and working group (less and more than 5 years working experience) and as predictors. Result of the analysis showed that working group was the significant predictor of increased of FEV1/FVC. These results showed synergistic relation between effects of number of smoking years and welding exposure for more and less than 5 years working experience causing restrictive disorder in Plant 1.

Plant 2: Further analysis by multiple regressions confirmed number of working years contributes 16.3% of the variance in FVC. Number of working years was also the significant predictor to the decreased values of FVC. However, number of smoking years and type of welding was not the significant predictors of FVC.

Further analysis by multiple regressions confirmed number of working years contributes 15.9% of the variance in FEV1. Number of working years was also the significant predictor to the decreased values of FEV1. However, number of smoking years and type of welding was not the significant predictors of FEV1.

Plant 3: Further analysis by multiple regressions confirmed number of working years contributes 9.3% of the variance in FEV1/FVC. Number of working years was also the significant predictor to the increase values of .However, number of smoking years and type of welding was not the significant predictors of FEV1/FVC.

In Table VI, mean values of FVC, FEV1, FEV1/FVC and PEF or Plant 1 were adjusted with smoking years. Mean number of cigarette smoke by welder were 7, 3 and 4 for Plant 1, 2 and 3 respectively. It is clear that welders in Plant 1 smoke in average 2 times higher (number of cigarette) than Plant 2 and 3. Only smoker with below than 10 years smoking duration were selected for Plant 1. This exclusion decreased the average number of cigarette smoke for Plant 1 from 7 to 5. Since smoking years were not the significant predictors for Plant 2 and 3, no adjustment towards smoking years were made for these plants. It was found that index value was in the same agreement with pulmonary functions for all plants.

Result in Table VI shows that welders in Plant 2 suffer the most on decreased value of FVC, FEV1 and PEF lung functions. Welders in Plant 2 also have the highest value of FEV1/FVC ratio suggesting restrictive disorder when adjusted for smokers.

TABLE VI. MEAN VALUES OF LUNG FUNCTIONS FOR CONTROL, PLANT 1 (ADJUSTED), PLANT 2 AND PLANT 3

Criteria	Control n=52 (mean ±SD)	Plant 1 n=23* (mean ±SD)	Plant 2 n=53 (mean ±SD)	Plant 3 n=44 (mean ±SD)
Age	34.56 ±7.65	28.00 ±9.17	30.62 ±5.96	28.84 ±5.55
FVC (% pred)	88.33 ±12.19	89.65 ±13.23	84.09 ±15.79	87.86 ±13.20
FEV_1 (% pred)	94.58 ±12.40	91.96 ±11.27	88.51 ±15.30	91.14 ±12.99
FEV_1/ FVC	107.94 ±6.38	102.96 ±6.65	105.91 ±9.89	103.61 ±5.55
PEF (% pred)	84.67 ±11.93	80.565 ±12.55	68.58 ±16.07	71.68 ±14.50

V. CONCLUSION

It can be concluded that although welding fumes exposure were well below the permissible limit for all plants, welders in all plants suffer from decreased lung functions compare to control groups. Welders in Plant 2 suffer the most on decreased value of FVC, FEV1 and PEF lung functions. Welders in Plant 2 also have the highest value of FEV1/FVC ratio suggesting restrictive disorder which was common in welders. Thus it is advisable that welders and company management work together to adopt technical preventive and control measures to reduce exposure of welding (using a less hazardous welding agent, installation of local exhaust ventilation, wearing suitable respiratory protective equipment). It is also suggested for the welder to undergo medical surveillance tests periodically.

ACKNOWLEDGMENT

This work was supported by the Exploratory Research Grant Scheme (ERGS) vote E003 under the Malaysian Ministry of Education. The authors gratefully

acknowledge the cooperation given by the company management and all the welders that had took part in this study.

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