A literature review: The relationship between welding fume exposure and welders' lung function disorders: toxicological study

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ABSTRACT

Background: Welding is the process of combining two types of metal or other material particles into one by melting and cooling processes. Welding fumes and welding metal fumes have a risk of lung function disorders in welding workers.
Objective: This study aimed to discover the relationship between the effect of exposure to welding smoke and pulmonary function disorders in welding workshop workers based on the years of service and the use of PPE (masks).
Methods: This research was a literature review using secondary data sources through the Google Scholar and Pubmed databases published in 2010-2020.
Results: Vital lung capacity of ≥ 5 years welders have a higher risk of having lung function disorders. Welders who use PPE (masks) as many as 48 workers (21%) and 179 workers (79%) do not use PPE (masks) during the work. Welders who do not consistently wear masks are twice as likely to have lung function disorders.
Conclusion: Welders having years of service ≥ 5 years are more at risk of experiencing lung function disorders than years of service < 5 years. The mask usage affects the welders' lung function health.

Keywords*: Lung Functional Disorders, Welders, Welding Fume*

INTRODUCTION

Welding is the process of melting and cooling two different types of metal or other material particles into one.[1] The process of melting metal using heat energy and applying it to the metal portions that will be bonded.This metal joining method can be done using pressure or without. Many innovative welding procedures have been developed in accordance to development of science and technology.[2]

Welding has a hazard risk because it produces dust, gases, explosive materials, radiation, electric shock hazard and welding spark hazard.[3] Dust from the welding process enters through inhalation. The dust particles that can be inhaled while breathing are between 0.1-10 µm. Welding dust that enters the respiratory tract depends on the particle size. If inhaled, welding fume dust with a particle size of 5 µm or bigger is caught in the nasal hairs and breathing tubes.Welding fume dust with smaller particles enters the lungs and is exhaled in some cases.Shortness of breath can be caused by welding fumes that stick to the air spaces in the lungs.Particles with a diameter of 1-3 µm can enter the respiratory tract and enter the alveoli, but small particles measuring 0,1-1 µm will carry out brown movements and may hit the surface of the alveoli and be buried there. Dust that enters the alveoli then the

alveolar tissue will harden. As a result, if 10% of the alveolar tissue hardens, its elasticity in accommodating the volume of air decreases, the ability to bind oxygen decreases and lung capacity decreases.[4]

Welding workers have the most dominant influence as the cause of pulmonary function disorders, which is according to the period of work with a p value of 0.007.[5] Decreased lung function is a symptom of a respiratory disease that effects the body's metabolism and reduces productivity at work.[6] When workers are exposed to dust, their lung function degrades. Spirometry is used to identify pulmonary function problems. Spirometry examination results can be classified as restrictive, obstructive and a combination of restrictive and obstructive. Restrictive lung disorders are a decrease in the ability to enter air into the lungs (inspiration) and a decrease in normal lung volume. Obstructive pulmonary disorders are narrowing of the diameter of the airways, making it more difficult for air to be expelled (expiration).[7] Combination of restrictive and obstructive pulmonary function disorders is caused by pathological processes that cause reduced lung volume, vital capacity and flow involving the airways in breathing. [8]

Working in a welding workshop if not careful can lead to danger. Prevention for workers includes: raising the awareness of the welder to use personal protective equipment, performing welding work safely and comfortably to avoid hazards caused by welding fumes. Based on this background, researchers are interested in conducting a literature study on the correlation between the effects of exposure to welding fume and impaired lung function in welding workshop workers based on years of service and use of PPE (Personal Protective Equipment).

METHODS

This research uses a literature review, namely by identifying, reviewing and evaluating certain relevant research.[9] This study used secondary data sources through the Google Scholar and Pubmed databases published in 2010-2020. The inclusion criteria for this study were articles/ reviews/ dissertations, specifically spirometry, Indonesian literature, and English literature. Exclusion criteria were the absence of full text, literature published under 2010. Journals that found the inclusion and exclusion criteria were identified to obtain relevant sources, analyzed and synthesized. The pattern of keywords in this study is presented in Table 1.

Table 1. Research Keyword Table

No	PICO	Keyword
1.	*Population/Problem*	*Welding worker*
2.	*Intervention*	*Exposure to welding fume/respirable dust*
3.	*Comparison*	-
4.	*Outcome*	*Pulmonary function disorders*

RESULT AND DISCUSSION

Search results for electronic journals obtained from Google Scholar and Pubmed databases with keywords "*welding worker*", "*exposure to welding fume/respirable dust*" and "*pulmonary function disorders*" are presented in Table 2.

Table 2. Literature Search Results

No	*Database*	Search Method	Number of Relevant Journals Found
1.	PubMed	*Welding worker* *Exposure to welding fume* *Pulmonary function disorders*	1
2.	*Google Scholar*	*Welding worker* *Exposure to welding fume/respirable dust* *Pulmonary function disorders*	13

Based on the search method that has been carried out, there are 14 journals that meet the criteria and are relevant to the problem and purpose of this study.

Exposure to welding fume with *Pulmonary function disorders* according to the period of work

Welding workers are at high risk for exposure to welding dust containing fume or metal fumes. Some of the results of studies looking at the effects of welding fume exposure on the decline in lung function in welders by the period of work are summarized in Table 3.

Table 3. The Correlation of Pulmonary Function with Working Period

Reseaercher	Working Period Group (years)	Reseaerch Result (Pulmonary Function Condition)	Conclusion
Desy, R. dan Lilis S, (2018)	23 workers from 4 welding workshop < 5 5-10 > 10	N= 7 (87.5 %) ; TN= 1 (12.5%) N= 1 (100%) ; TN= 0 (0.0%) N= 12 (85.7%) ; TN= 2 (14.29%)	3 workers had pulmonary function disorders in the category of mild obstruction and restriction. The highest fume level was 32.1 mg/m^3 and the lowest fume was 0.4 mg/m^3.
Nurkhaleda, *et al.* (2016)	37 workers ≥ 5	N= 14 (60.9%) ; TN= 9 (39.1%)	There is no correlation between years of working period and

Reseaercher	Working Period Group (years)	Reseaerch Result (Pulmonary Function Condition)	Conclusion
	< 5	N= 9 (64.3%) ; TN= 5 (35.7%)	pulmonary function capacity (p value = 1.00).
Febrianto, *et al.* (2015)	36 workers from 5 welding workshop < 5 5-10 > 10	N= 5 (100%) ; TN= 0 (0.0%) N= 11 (64.7%) ; TN= 6 (35.3%) N= 5 (35.7%) ; TN= 9 (64.3%)	There is a correlation between years of working period and pulmonary function disorders (p value = 0.009). Welding smoke dust level 10 mg/m3 with abnormal lung function = 15, normal = 21.
Deviandhoko, *et al.* (2012)	78 pekerja ≥ 5	N= 59 (75.6%) ; TN= 19 (24.4%)	There is a correlation between years of working period and pulmonary function disorders (*p value* = 0.609). The highest fume level was 2.791 mg/m^3 and the lowest fume was 0.085 mg/m^3. The average of respirable dust particles inhaled by welding workers is 0.83 mg/m3.
Pasaribu (2017)	34 workers from 8 welding workshop < 5 ≥ 5	N= 7 (46.7%) ; TN= 8 (53.3%) N= 12 (63.2%) ; TN= 7 (36.8%)	There is a correlation between years of working period and pulmonary function disorders (*p value* = 0.336). The highest fume level was 0.582 mg/m^3 and the lowest fume was 0.155 mg/m^3.
Sukawati, *et al.* (2014)	47 workers from 19 welding workshop ≥ 5	*p value* < 0,001 with PR 95% CI = 9.257 (1.405-60.981)	There is a correlation between years of working period and pulmonary function disorders (*p* < 0.001). Dust level between 0.248-2.083 mg/m^3. Mean = 1.18 mg/m^3.
Novandany (2014)	42 workers ≥ 10 < 10 Mean: 6	Lung Vital Capacity N= 16 (38.1%) ; TN= 26 (61.9%)	There is a correlation between years of working period and pulmonary function disorders (*p value = 0.014*). The highest fume level was 11.142 mg/m^3 and the lowest fume was 0.454 mg/m^3. Mean = 6.222 mg/m^3.
Koh, *et al.* (2015)	240 workers < 10 10-19 20-29 ≥ 30 Mean: 15	N= 8 (22%) ; TN= 83 (41%) N= 8 (22%) ; TN= 43 (21%) N= 9 (24%) ; TN= 51 (25%) N= 12 (32%) ; TN= 26 (13%)	There is a correlation between exposure to welding fumes and an increase in chronic obstructive pulmonary disease. Cumulative smoke exposure averaged 7.7 mg/m^3.
Golbabaei, *et al.* (2013)	91 workers 25 controls > 5	*Pre-shift* FVC = 86.40±9.42% FEV1 = 87.83±9.48% FEV1/FVC = 94.17±9.53% *Post-shift* FVC = 81,51±9.54% FEV1 = 79,21±11.52% FEV1/FVC = 72,60±7.41%	Decreased FEV1, FEV1/FVC and peak expiratory flow relative to the control group.
Stoleski, *et al.* (2015)	39 workers ≥ 12	FVC = 86.2±8.9% FEV1 = 82.1±7.1% FEV1/FVC = 73.6±3.1%	There is a decrease in the spirometry index.

Reseaercher	Working Period Group (years)	Reseaerch Result (Pulmonary Function Condition)	Conclusion
	≤ 12	FVC = 88.7±6.5% FEV1 = 84.8±5.2% FEV1/FVC = 74.8±4.0%	

Inhalation of high concentrations of metallic vapors can cause irritation to the respiratory tract. Based on the results of the study, it was stated that there was a relationship between working period and decreased pulmonary function capacity due to exposure to dust, the highest fume level was 11.142 mg/m^3 and the lowest fume was 0.454 mg/m^3. The average fume level in this study was 6.222 mg/m^3.[10] This is supported by subsequent research which suggests that there is a relationship between working period and pulmonary function disorders in welding workers in Ngagel Village, Wonokromo District, Surabaya City with welding smoke dust levels 10 mg/m^3. This is because the longer the working hours, the more particles will settle in the worker's body if the particles that settle in the body over a long period of time can cause pulmonary dysfunction or lung disease in the worker.[11]

Another study also stated that lung function in 3 welding workers had abnormal lung function. The highest fume level in this study was 32.1 mg/m^3 and the lowest fume was 0.4 mg/m^3, the workers had disorderd lung function in the category of mild obstruction and restriction.[12] The average working period was 15 years and the cumulative exposure was 7.7 mg/m^3, where the odds ratio for COPD was significantly higher in the medium and high exposure groups compared to the low smoke exposure group.[13] Stoleski, et al. (2015)[1] stated that there was a respiratory effect in welders with a working period of 12 years compared to 12 years. Welders with exposure 5 years showed a significant decrease in the spirometric index relative to the control group.[14] In line with the study of lung function of welding workers in Mertoyudan Magelang District, the dust content in this study was between 0.248-2.083 mg/m^3 with a mean = 1.18 mg/m^3. Working hours are the most predominant cause of acute pulmonary dysfunction.[6]

Welding workers who have worked ≥5 years are 24 times more likely to have impaired lung function compared to those who have worked ≤ 5 years. These various studies prove that the working period is too long, the more particles that settle in the workers bodies. It is concluded that the longer a person's working period and the longer the exposure time will have an impact on lung function disorders and the greater the possibility that someone has a risk of lung disease.

Another research reported that there was no correlation between length of service

and lung function capacity (p value = 1.00). Working period of ≥ 5 years in the study 39.1% of workers had abnormal lung function while workers with < 5 years of working period were 35.7%.[15] This case is in line with a study conducted in Pontianak City, there was a decrease in vital lung capacity. Abnormal lung function in welding workers was 24.4% but there was a significant relationship between inhaled welding dust (p value = 0.001). The highest fume level in this study was 2.791 mg/m^{3}and the lowest fume level was 0.085 mg/m^3, the average inhaled dust particles inhaled by workers was 0.83 mg/m^3.[16] It can be concluded that welding dust fumes containing metals will cause irritation of the respiratory tract, obstruction and fibrosis of the lungs. Other research results that are in line with this state that there is no significant relationship between years of service and lung function disorders with p value = 0.336. The highest fume level was 0.582 mg/m^3 and the lowest fume was 0.155 mg/m^3. The results of the research showed that 19 workers had normal lung function, where 12 other workers had ≥ 5 years of service and 7 of them had <5 years of working period. In addition, 15 workers experienced pulmonary function disorders, of which 8 workers with a working period of < 5 years and 7 workers with a working period of ≥ 5 years.[17] Working period has no direct correlation to the occurrence of respiratory function disorders, but can be a risk factor for the occurrence of respiratory disorders. respiratory function. This is caused by the variable length of working period not directly or there are other factors to affect respiratory function disorders.[18]

Exposure to welding fume with *Pulmonary function disorders* according to the Personal Protective Equipment

The use of PPE can minimize workers from exposure to dust which can have an impact on the lung function of the welder if this takes place over a long period of time.[19] The distribution of the correlation between PPE and lung function disorders can be seen in Figure 1.

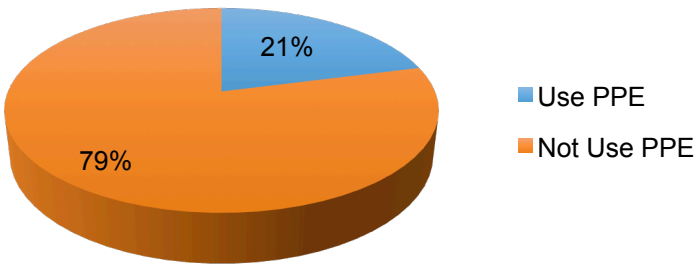

Figure 1. Welker Frequenty Distribution Based on PPE Usage

Based on Figure 1, it shows that 48 workers (21%) use PPE and 179 workers (79%) do not use PPE at work. Several results from studies relating to the effects of welding fume exposure on impaired lung function in welding workers based on PPE are summarized in Table 4.

Table 4. Lung Function Disorders According of PPE Usage

Researcher	PPE Usage (mask)	Lung Function Disorders (=n)	p-value	information
Slamet dan Laila K (2017)	Use= 71 (91.1%) Not Use= 7 (8.9%)	TN= 19 (24.4%) N= 59 (75.6%)	1.000	Not Significant
Nurkhaleda, *et al.* (2016)	Not Use= 13 (35.1%) Use= 24 (64.9%)	N= 3 (23.1%); TN= 10 (76.9%) N= 20 (83.3%); TN= 4 (16.7%)	0.001	Significant
Deviandhoko , *et al.* (2012)	Not Use= 71 (91.1%) Use= 7 (8.9%)	TN= 19 (24.4%) N= 59 (75.6%)	1.000	Not Significant
Pasaribu (2017)	Not Use= 24 (70.6%) Use= 10 (29.4%)	N= 10 (41.7%); TN= 14 (58.3%) N= 9 (90.0%); TN= 1 (10.0%)	0.020	Significant

Research by Slamet and Laila K (2017)[20] and Deviandhoko, et al. (2012)[17] stated that the highest fume content was 2.791 mg/m^3 and the lowest fume was 0.085 mg/m^3. The study found that the average of respirable dust particles inhaled by welding workers was 0.83 mg/m^3. It can be concluded that there is no significant correlation between the use of PPE (p value = 1.000) with lung function disorders in welding workers in Pontianak City.[17, 20]

However, workers wearing the correct masks can provide significant protection. Nurkhaleda, et al. (2016)[15] explain that there was a correlation between the use of masks and lung function capacity in welding workers with a probability value of 0.001. This is supported by research conducted by Pasaribu (2017)[17] which states that there is a significant correlation between the use of PPE and lung function disorders and a probability value of 0.020 is obtained with the highest fume level of 0.582 mg/m^3 and the lowest fume being 0.155 mg/m^3. The highest respiratory symptoms were caused by shortness of breath, exposed (22.7%) and unexposed (10%).[21] Another study stated that there was a correlation between the use of PPE (masks) and vital lung capacity.[22] Workers who sometimes wear respiratory protective equipment are at risk twice as large as workers who always wear respiratory protective equipment while working. This study is also in line with research conducted by Fathurrahman (2014) which suggests that there is a correlation between the use of PPE (respirators) and lung function disorders with a probability value of 0.016.[23]

Various types of respiratory diseases in welding worker are: rhinitis, asthma, chronic bronchitis, emphysema, pulmonary edema, pneumonia, pneumoconiosis, inhalation fever, lung cancer, decreased lung function and cardiovascular disorders. The study also found that the effects of factors such as inhalation of welding fumes were not apparent in the short term. Research also explain that during the welding process, the metal welding fumes are heated and cooled rapidly. This process leads to the movement of small solid particles in the air, which can be the underlying cause of lung disease.[24]

The use of PPE in workers is very important as it can prevent the emergence of an occupational disease and accident. Based on the results of the Spearman correlation test, there is a correlation between the use of respiratory personal protective equipment with vital lung capacity with a probability value of 0,0001.[25] Workers who do not use standard masks are at risk of lung function disorders. The use of PPE really helps minimize workers from exposure to dust which can have an impact on workers' lung function, if this happens for a long period of time.[19]

CONCLUSION

Based on the results of the study, it can be concluded that workers with a working period of ≥5 years are more at risk of having pulmonary function disorders than those with a working period of <5 years. Welders who don't consistently wear masks are twice as likely to have a decreased lung function. The fume factor resulting from welding affects the vital capacity of the workers' lungs, although the level of fume produced is small, in the long term it can affect lung function.

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