

## A META-ANALYSIS OF RISK FACTORS OF LENGTH OF EXPOSURE, SMOKING HABITS, USE OF PERSONAL PROTECTION EQUIPMENT (PPE), AND EXPOSURE TO WELDING FUMES IN WELDING WORKERS WITH ABNORMAL PULMONARY FUNCTION (A PERSPECTIVE OF SUSTAINABLE PUBLIC HEALTH)

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### Abstract

**Introduction:** About 11 million workers are welders worldwide, and more than 110 million workers are exposed to welding-related jobs. As many as 75.6% of welding workers in Pontianak, West Kalimantan, Indonesia, suffer from abnormal pulmonary function due to exposure to welding fumes. This study analyzed some risk factors and their sensitivity of abnormal pulmonary function in welding workers. **Discussion:** This study is a meta-analysis article. Data sources were obtained from articles published online on Google Scholar, Science Direct, Pubmed, and Springer from 2010 to 2020. A total of 15 articles were selected for meta-analysis using JASP version 0.9.2 software. Results showed pooled prevalence ratio (PR) values of long-exposure variables of 1.954 (95% CI = 0.31–1.03), smoking habits of 2.159 (95% CI = 0.33–1.22), USE of PPE 1.491 (95% CI = -0.50–1.30) and exposure to welding fumes 2.271 (95% CI = 0.52–1.12) in welding workers with abnormal pulmonary function. **Conclusion:** Exposure to welding fumes and smoking habits are the highest risk factors causing abnormal pulmonary function in welding workers. For workers, it is expected to reduce or stop smoking and always use PPE at work. For industry, control efforts are required by rotating work, conducting periodic worker medical examinations, providing exhaust with blowers in the workspace, and reinforcing the use of PPE at work.

## INTRODUCTION

Welding is a critical process in industrial technology. Welding techniques mostly involve splicing of various metals. Welding is the process of splicing two metals, whether similar or not in types and added materials, by using heat energy to the point of metal recrystallization to dilute some of the parent metal (1-2). It is estimated that about 11 million workers worldwide are welders, and more than 110 million workers are exposed to welding fumes (3). Welding fumes are produced when a metal is heated to above its melting point, and it evaporates, and condenses into fumes. Metal particles are less than one  $\mu\text{m}$  that have solidified

from the gaseous state (3-4). The toxicity of welding fumes depends on particle size, distribution, morphology, chemical composition, concentration, length of exposure, welder concision, number of operating welders, welding length, and thickness of the material spliced which determines the number of fumes produced (5-6). Moreover, judges from the risk score calculated based on hazard rate (HR) and exposure rate (ER), the most dangerous component of welding fumes is chromium (7). Chromium (VI) or hexavalent chromium is one of the toxic heavy metals widely used in various industries, including chrome coating (8). Chromium (VI) changes during the welding process are caused by the oxidation of Metals Cr, and Chromium (III) by ozone or certain alkaline oxides

in protected flux, which can form stable Chromium (VI) compounds that are suspected carcinogens (9).

Welding fumes can interfere with work comfort, visual impairment, general cause intoxication, and abnormal pulmonary function (10). Long-term exposure to welding fumes is associated with respiratory health problems, including asthma, bronchitis, changes in lung function, neurological disorders, cardiac arrhythmias, myocardial ischemia, atherosclerosis, and increased risk of cardiovascular disease e.g, hypertension (3). A study in Malaysia showed that welding workers suffered from coughing (17.5%), phlegm (21.4%), shortness of breath (14.3%), wheezing (14.3%), emphysema self-reported (3.6%), emphysema diagnosed by doctors (3.6%), asthma self-reported (14.3%), and asthma diagnosed by doctors (10.7%) (11). Besides, welding fumes have contributed 39.28% to the increase in lung damage in welding workers because of the chemical toxicity and long-term exposure (11). Regarding this, welding workers are at risk of exposure to higher welding fumes. Research conducted to fabrication workers at PT Pertamina (Persero) RU (Refinery Unit)-VI Balongan, Indramayu Regency found that the exposure to welding fumes was high with a severity value of 2 (moderate) and likelihood value of 4 (frequent) (12). Research in a shipbuilding industry factory in Iran showed that 57% of welding workers suffered from abnormal pulmonary function because of exposure to welding fumes (13). Research in Pontianak, West Kalimantan, Indonesia showed that 75.6% of welding workers had abnormal pulmonary function with a similar cause (14). Dose, length of exposure, and composition of welding fumes are able to likely affect abnormal pulmonary function (15).

Spirometers can be used for examining lung function. Spirometry examination can show dynamic volumes including PEFR (Peak Expiratory Flow Rate), MBC (Maximal Breathing Capacity) or MVV (Maximal Voluntary Ventilation),  $FEF_{200-1200}$  (Forced Expiratory Flow<sub>200-1200</sub>),  $FEF_{25-75}$  (Forced Expiratory Flow<sub>25%-75%</sub>), FEV<sub>1</sub> (Forced Expiratory Volume), and FVC (Forced Vital Capacity). A person who has an obstruction will show a decrease in standard vital capacity and the speed of expiratory flow in addition to decreased vital lung capacity because of more intense airflow and trapping air. FEV<sub>1</sub>/FVC is a widely used FEV value and is abnormal if reaching <80%. FEV<sub>1</sub>/FVC would be normal if the FVC value were deficient (16).

A study in welding workers showed that abnormal pulmonary function had a meaningful relationship with the length of exposure to welding fumes ( $p = 0.008$ ; OR = 6.321; 95% CI = 1.663–24.026), and workers

who performed welding for  $\geq 8$  hours/day had a smaller average lung capacity than for <8 hours/day (14). Exposure to welding for  $\geq 8$  hours/day puts workers 6,321 times greater at risk of suffering from abnormal than for <8 hours/day. In addition to the length of exposure, research at the maintenance section of PT. KAI at Semarang Poncol Locomotive Dipo showed that 72.7% of welding workers who experienced abnormal lung function had smoking behavior, and smoking habits had a significant association with abnormal pulmonary function ( $p = 0.009$ ) (17). Exposure to cigarette smoke and welding fumes has a synergistic effect on decreased pulmonary function among welding workers who smoke (18). Supporting the statement, research in Unizah, Qassim, Saudi Arabia, showed that workers who were simultaneously exposed to welding fumes and had smoking habits had worse pulmonary function (19).

Research in Punjab, India, showed that using personal protective equipment (PPE) is significantly associated with abnormal pulmonary function in welding workers (20). No use of PPE at work results in high risk of abnormal pulmonary function (21). Besides, research at the Moss shipyard, Perak, Malaysia showed that exposure to welding fumes is associated with abnormal pulmonary function. It found FEV<sub>1</sub> and FVC in welding workers are lower than non-welding workers (22). Research in Lahore, Pakistan, showed that exposure to welding fumes at work is significantly associated with abnormal pulmonary function (23). Preventive measures are necessary to overcome health problems, especially abnormal pulmonary function, in welding workers.

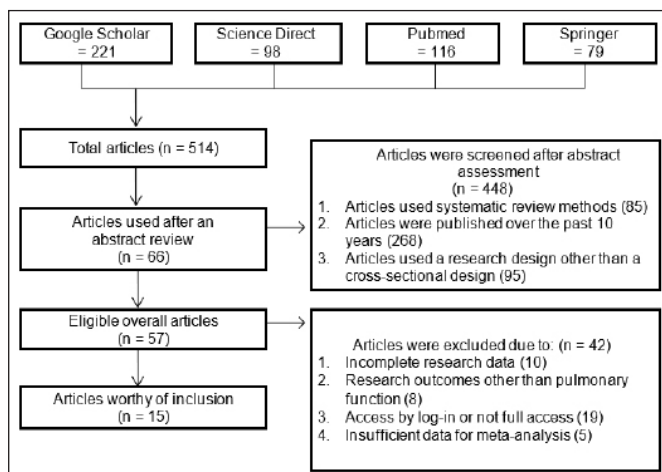
The study aimed to analyze long-standing risk factors such as exposure, smoking habits, PPE use, and exposure to welding fumes and their sensitivity that might be associated with abnormal pulmonary function in welding workers.

## DISCUSSION

This article is a meta-analysis article. Data were collected from journal articles and thesis that have been published online on Google Scholar, Science Direct, Pubmed, and Springer from 2010 to 2020. The search was done through Boolean logic/operator, namely OR and AND. Some keywords used were "Length of exposure" OR "Time exposure" AND "Smoke" OR "Smoking" AND "Personal protective equipment" AND "Welding fumes" AND "Pulmonary function disorder" OR "Lung function".

The inclusion criteria included; articles discussing the long-standing relationship between exposure to welding fumes, smoking habits, use of personal protective equipment (PPE), exposure to welding fumes,

and abnormal pulmonary function; articles published from 2010 to 2020; articles conducted in welding workers; articles using a cross-sectional design; articles in Indonesian or English; full-text articles; articles analyzing the data. Fifteen articles were selected for meta-analysis (Figure 1).



**Figure 1. Selection of Articles for Meta-Analysis of Risk Factors Associated with Abnormal Pulmonary Function in Welding Workers**

This study used a fixed effect analysis model or random effect analysis model. If the variation between variables was homogeneous ( $p > 0.05$ ), the fixed effect model analysis model would be used. If the variation between variables was heterogeneous ( $p < 0.05$ ), then the random effect model analysis model was used. The pooled odds ratio estimate was obtained after the use of Mantel-Haenszel analysis for the fixed-effect analysis and the DerSimonian-Laird analysis for the random effect analysis. A meta-analysis was performed using JASP version 0.9.2 software.

The meta-analysis calculated the prevalence ratio (PR) value with a confidence interval (CI) of 95%. If the CI value of 95% passed 1 (95% CI  $> 1$ ), then the variable was a risk factor. If the CI value of 95% did not pass 1 (95% CI  $< 1$ ), then the variable was not a risk factor but was included in protective factors. In this study, four variables e.g., length of exposure, smoking habits, use of PPE, and exposure to welding fumes were included as risk factors for abnormal pulmonary function in welding workers. The variables had the value of pooled PR  $> 1$ , and 95% CI passed 1. Besides, a publication bias test was used using funnel plot in addition to sensitivity tests by comparing the analysis results.

**Meta-Analysis of Length of Exposure to Welding Fumes with Abnormal Pulmonary Function in Welding Workers**

In this study, there were five research articles that analyzed the long-standing relationship of exposure to abnormal pulmonary function in welding workers

in Indonesia (14,24–27). The articles used a cross-sectional design.

Based on Table 1, the heterogeneity tests showed a p-value greater than 0.05 ( $p = 0.354$ ), meaning the variation between the studies was homogeneous. Since there was no variation between the variables, the fixed-effect analysis model was used. The selected articles displayed the relationship between length of exposure and abnormal pulmonary function in the forest plot (see Figure 2). It showed that the pooled prevalence ratio value was 1.954 (95% CI = 0.31-1.03). The publication bias test was not carried out on the length of exposure because there were only five studies out of minimum ten articles.

Long exposure is the length of time a worker can work and get exposed to the work environment in one day, calculated in hours. In this study, the length of exposure is classified into two categories:  $> 8$  hours per day and  $< 8$  hours per day. Figure 2 shows that the pooled prevalence ratio is 1.954 (95% CI = 0.31-1.03). Workers exposed to welding fumes for more than 8 hours/day had 1.954 times greater risk of experiencing abnormal pulmonary disorder than for less than 8 hours/day.

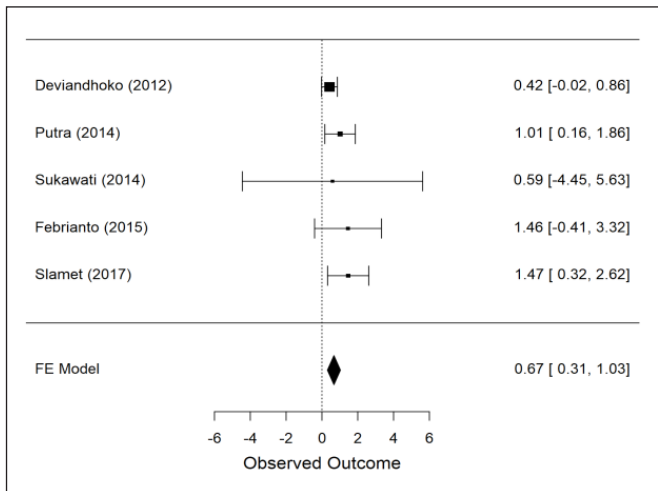
Based on the Government Regulations of Republic Indonesia No. 13 Year 2003 about Employment, working time is 8 hours per day or 40 hours per week (34). The standard time for a person working aims to maintain the health and safety of workers. If a person works beyond the standard, then she/he will likely experience health problems or diseases at work.

Research in Nigeria showed abnormal pulmonary function was significantly related to the length of work by welding workers (35). The longer the exposure to welding fumes, the greater the risk of abnormal pulmonary function (23,36). Besides, prolonged exposure to welding fumes is associated with pulmonary function status. The long exposure to welding fumes leads to a significant decrease in pulmonary function parameters including FVC, FEV<sub>1</sub>, FEV<sub>1</sub>/FVC, and MVV in welding workers (37).

Research in Ankara, Turkey showed significant differences in FEV<sub>1</sub>% and FEV<sub>1</sub>/FVC ratio welding workers who worked more than 4 hours/day from the control group. FEV<sub>1</sub>% was predicted to be lowest with 80.5% occurring in welding workers exposed to welding smoke more than 4 hours a day, and the lowest FEV<sub>1</sub>/FVC ratio with 89.4% occurred to the group exposed for more than 4 hours/day, followed by exposure for less than 4 hours per day in 95.9% and 102.8% of the control group (38). Furthermore, the lowest PEF occurred to 80.6% of the group exposed for more than 4 hours/day, followed by exposure for less than 4 hours/day in 89.6% and 90.6%

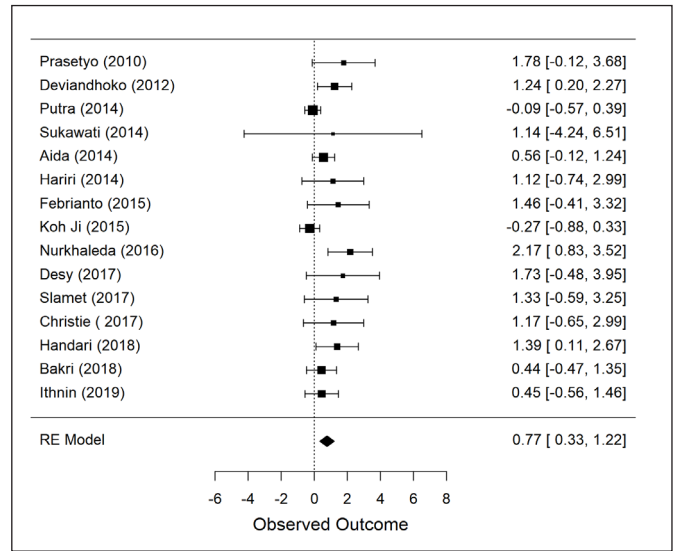
of the control group (38). Research in Semarang, Central Java found welding workers exposed to welding fumes for 10 hours/day with a working period of  $\geq 5$  years were at risk of suffering from abnormal pulmonary function (17). Similar findings were found in welding workers who worked for 5-11 hours/day and had an average working period of 5 years in the Shuaiba industrial area, Kuwait. The research found an association between length of exposure and abnormal pulmonary function (39).

Therefore, efforts are warranted to minimize, prevent, and reduce the risk factors for abnormal pulmonary function in welding workers. For example, the companies have to apply strict laws and regulations at work, provide technical training on welding and occupational health and safety, as well as appropriate orientation sessions on workplace hazards. In addition to these efforts, the companies have to conduct regular medical check-ups in the workers.



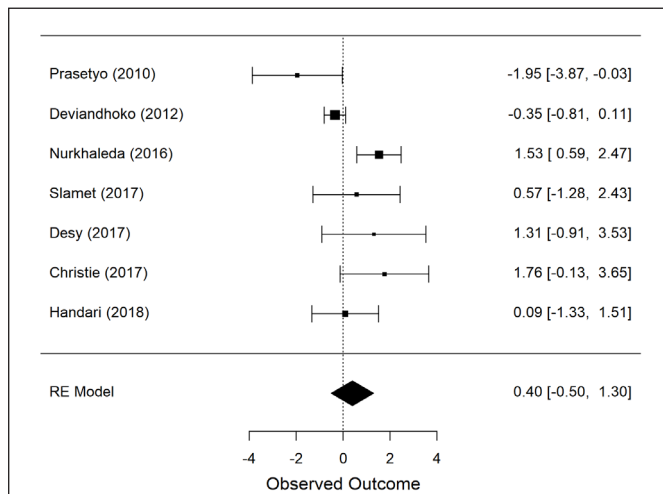
Pooled PR value =  $e^{0.67} = 1.954$

(a)



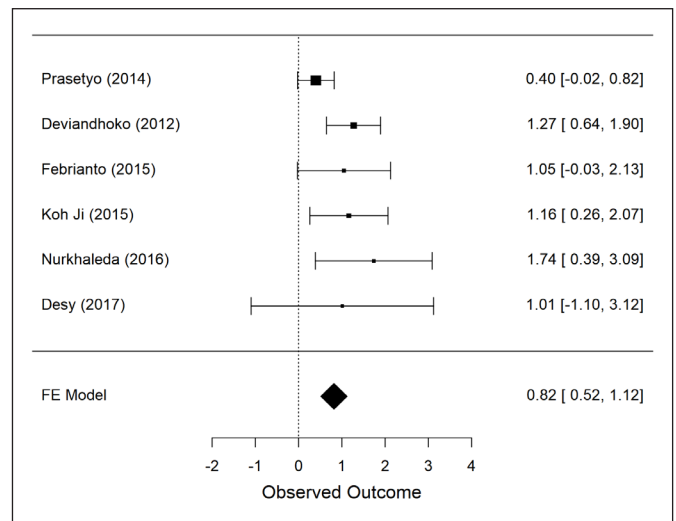
Pooled PR value =  $e^{0.77} = 2.159$

(b)



Pooled PR value =  $e^{0.40} = 1.491$

(c)



Pooled PR value =  $e^{0.82} = 2.271$

(d)

Description:

- : Black square shows weight of each study
- ◆ : Black diamond shows pooled PR
- : Horizontal line indicates 95% CI

**Figure 2. Forest Plot of Risk Factors for Abnormal Pulmonary Function in Welding Workers**

(a) Forest plot of length of exposure; (b) Forest plot of smoking habits; (c) Forest plot of use of Personal Protection Equipment (PPE); (d) Forest plot of exposure to welding fumes.

**Meta-Analysis of Smoking Habits in Association with Abnormal Pulmonary Function in Welding Workers**

Fifteen articles were analyzed for the relationship between smoking behavior and abnormal pulmonary function in welding workers (11,14,17,21–22,24–33). Those articles used a cross-sectional design.

**Table 1. Heterogeneity Test of Risk Factors in Welding Workers**

Meta-Analysis Using Heterogeneity Test		Q	df	p
Length of Exposure to Welding Fumes in Association with Abnormal Pulmonary Function in Welding Workers Analysis model: Fixed effects model	Omnibus test of model coefficients	13.145	1	<0.001
	Test of residual heterogeneity	4.406	4	0.354
Smoking Habits in Association with Abnormal Pulmonary Function in Welding Workers Analysis model: Random effects model	Omnibus test of model coefficients	11.84	1	<0.001
	Test of residual heterogeneity	27.26	14	0.018
Use of Personal Protection Equipment (PPE) in Association with Abnormal Pulmonary Function in Welding Workers Analysis model: Random effects model	Omnibus test of model coefficients	0.750	1	0.387
	Test of residual heterogeneity	21.283	6	0.002
Exposure to Welding Fumes in Association with Abnormal Pulmonary Function in Welding Workers Analysis model: Fixed effects model	Omnibus test of model coefficients	28.233	1	<0.001
	Test of residual heterogeneity	8.293	5	0.141

Based on Table 1, the heterogeneity test indicated a p-value was smaller than 0.05 ( $p = 0.018$ ), meaning the variation between the studies was heterogeneous; the analysis was done using the random effect model. The forest plot showed the relationship between smoking habit and abnormal pulmonary function with a pooled prevalence ratio of 2.159 (95% CI = 0.33-1.22).

Based on Figure 3, the funnel plot results showed publication bias because the model was symmetrical. The black circle was partly outside the triangle area, and the Egger’s test was smaller than 0.05 ( $p = <0.001$ ).

Changes in respiratory tract function, structure, and lung tissue can be caused by smoking (32). Cigarettes have compounds that can settle in the lungs and thus harm them (17). In this study, the pooled prevalence ratio was 2.159 (95% CI = 0.33-1.22). It indicated welding workers who were smokers had 2.159 times greater to suffer from abnormal pulmonary function than those who did not smoke.

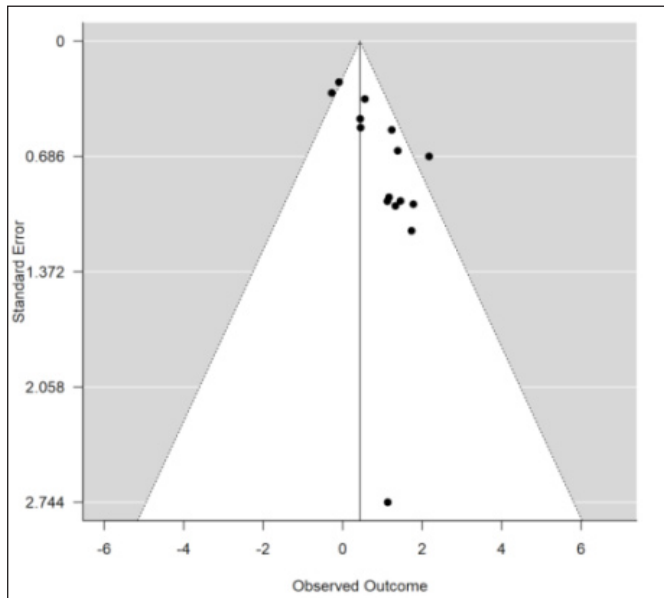
Smoking behavior is one of the factors that cause respiratory disorders (22). Research in Namibia showed that smoking behavior is associated with adverse effects on lung function (40). It is associated with a decrease in the spirometry index of lung function (41). Research in Semarang, Central Java discovered that, on average, welding workers who had smoking habits could consume 16 to 20 cigarettes/day. The lung capacity was related to smoking behavior among welding workers (31). The more the use of cigarettes, the higher the risk of abnormal pulmonary function (42). Research in Poland stated that welding workers who had smoking behavior had a lower FEV<sub>1</sub>/FVC ratio than those who were non-smokers. Thus, welding workers who have smoking habits are at risk of suffering from abnormal lung function (43).

Moreover, studies analyzing exposure to secondhand smoke and welding fumes simultaneously could decrease multiple spirometry indices, including %FEV<sub>1</sub>, %FEV<sub>1</sub>/FVC, FEV<sub>1</sub>/FVC, %PEF, %FEF<sub>25-75</sub>, and FEF<sub>25-75</sub> (44). This suggests a synergistic effect between exposure to cigarette smoke and welding fumes could aggravate lung conditions. Efforts are required to minimize and reduce the risk of abnormal lung function in smoking workers through health education on the harms of smoke. In addition, companies/agencies have to carry out regular medical check-ups to monitor the health status of their workers.

**Meta-Analysis of Use of Personal Protection Equipment (PPE) in Association with Abnormal Pulmonary Function in Welding Workers**

Seven research articles discussed the relationship between use of personal protection equipment and abnormal pulmonary function (14,17,21,24,31–33). The articles used a cross-sectional design.

The heterogeneity test showed a p-value was smaller than 0.05 ( $p = 0.002$ ), meaning the variation between the studies was heterogeneous. Thus, this analysis was done using a random effect model. Figure 2 showed the forest plot on seven research articles that discussed the relationship between use of PPE and abnormal pulmonary function in welding workers. It showed that the pooled prevalence ratio was 1.491 (95% CI = -0.50-1.30). The publication bias test was not carried out because the meta-analysis included less than ten studies.



**Figure 3. Funnel Plot of Smoking Habits Associated with Abnormal Pulmonary Function in Welding Workers**

The use of personal protective equipment (PPE) plays a crucial role in the occupational safety and health. It minimizes exposure to various hazards, thereby creating a healthier workplace (45). In addition, it has a significant relationship with occupational diseases in welding workers. For example, workers who did not wear PPE had 1.5 times greater risk of suffering occupational diseases than workers who wore PPE (46). Figure 2c shows with the pooled prevalence ratio of 1.491 (95% CI - 0.50 – 1.30), welding workers who did not use PPE e.g., masks had 1.491 times greater risk of suffering from abnormal pulmonary function than workers who wore PPE.

Research in Semarang, Central Java, showed a link between the use of masks and abnormal pulmonary function ( $p = 0.001$ ) (31). Masks can reduce inhalation of welding fumes (35). Research in Semarang, Central Java showed similar findings (31). Besides, research in Terengganu, Malaysia, found that the frequency of mask use had a positive and significant association with FVC values ( $p = 0.011$ ) (47).

Research in Delta, Nigeria, showed a significant association ( $X^2 = 233.893a$ ;  $DF= 3$ ;  $P<0.05$ ) between education level and use of PPE in welding workers (48). Research in Deli Serdang, North Sumatra, found that the use of PPE is significantly related to knowledge, attitudes, and actions performed by welding workers (49). The research pointed out that most of the welding workers were less knowledgeable due to insufficient information about the importance of using PPE at work. In addition, most welding workers had a negative attitude of using PPE since they did not understand the importance of using PPE for work safety.

Similarly, research in Binjai, North Sumatra, showed knowledge and especially attitude of workers affected the use of PPE (50). A study in Medan, North Sumatra, also found that workers who disregarded the use of PPE mostly did not know the benefits of using PPE. For example, they assume that face shields can be replaced by ordinary dark glasses. Reluctance to use PPE could reduce work productivity and cause rejection to using PPE (51).

Speaking about the support from the management, welding workshop owners did not impose much support on the use of PPE, and thus welding workers tend to take it for granted (51). This follows the research in Semarang, Central Java, showing that the length of work, work regulations, peer support, and leader support affected workers to use PPE (52). Proper and strict regulations regarding the use of PPE and respirators in welding industries successfully control exposure to heavy metal fumes (53).

Therefore, regulations must be placed to reinforce the use of PPE, such as face shields, welding helmets, glasses, gloves, welding masks, and respirators at work. Companies should educate workers on the importance of occupational safety and health, as well as push them to use PPE.

**Meta-Analysis of Exposure to Welding Fumes in Association with Abnormal Pulmonary Function in Welding Workers**

Six research articles collected discussed about the relationship between exposure to welding fumes and abnormal pulmonary function in Indonesia (24-25,27,30–32). All of them utilized a cross-sectional design.

Table 1 shows the variation between the studies was homogenous with a p-value of 0.141. This analysis was performed using the fixed effect model. The forest plot showed that the pooled prevalence ratio was 2.271 (95% CI 0.52 – 1.12). The publication bias test was not carried out to this variable for exposure since less than ten studies were included.

**Tabel 2. Comparison of Sensitivity Tests on Pooled Prevalence Ratio Using Fixed Model and Random Model**

Research Variables	n	Heterogeneity (p-value)	Fixed Effect Models		Random Effect Model	
			PR	95% CI	PR	95% CI
Length of Exposure	5	0.354	1.954	0.31-1.03	2.339	0.28-1.41
Smoking Habits	15	0.018	1.537	0.18-0.69	2.159	0.33-1.22
Use of Personal Protection Equipment (PPE)	7	0.002	1.073	-0.30-0.43	1.491	-0.50-1.30
Exposure to Welding Fumes	6	0.141	2.271	0.52-1.12	2.364	0.51-1.45

Test Sensitivity of Length of Exposure, Smoking Habits, Use of Personal Protection Equipment (PPE), and Exposure to Welding Fumes in Association with Abnormal Pulmonary Function in Welding Workers

Identifying heterogeneity, interpreting the effects of research quality, and proving relatively stable meta-analysis results can be done using sensitivity tests. The sensitivity test compared the pooled Prevalence Ratio (PR) fixed and random models. The comparison between the random model analysis model and the fixed model results can be seen in table 2.

Fumes are polluting pollutant materials or particulates produced from the welding process (54). The threshold limit value-time weighted average (TLV-TWA) value for exposure to fumes is  $5 \text{ mg/m}^3$  (3). Research conducted at PT. PAL Indonesia, the largest shipyard company in Indonesia, showed workers with abnormal pulmonary function worked in an environment with high exposure to welding fumes (32). In the current work study, with the pooled prevalence ratio of 2.271 (95% CI = 0.52-1.12). The workers who got exposed to fumes above the threshold had 2.271 times greater chances of suffering from abnormal pulmonary function compared to those under threshold value.

Exposure to welding fumes harms pulmonary function (44). Research in Stockholm, Sweden, showed that exposure to welding fumes was associated with abnormal pulmonary function (55). Research in Punjab, India showed a significant difference in the mean of the lung function parameters between welders and non-welders ( $p < 0.05$ ). The average of the FVC,  $FEV_1$ , and  $FEV_1/FVC$  ( $3.37 \pm .175$ ,  $2.59 \pm 0.16$ ) was significantly lower in welding workers than non-welding workers ( $3.70 \pm 0.15$ ,  $3.05 \pm 0.25$  and  $82.49 \pm 7.62$ ) (20).

Research in a steel industry company in Ahvaz, Iran, discovered that welding workers experienced a significant decrease in lung function for all parameters (FVC,  $FEV_1$ ,  $FEF_{25-75\%}$ , and  $FEV_1/FVC$ ) (56). In addition, research in Monza showed that based on the spirometry lung function tests, abnormal pulmonary function was correlated inversely with years of exposure to welding fumes ( $FEV_1$ :  $R^2 = 0.303$ ;  $p = 0.012$ ; FVC:  $R^2 = 0.27$ ;  $p < 0.02$ ). This indicates that the longer the exposure to welding fumes, the lower the  $FEV_1$  and FVC (57). Research in China showed that FVC,  $FEV_1$ , and PEF values of welding workers after work were significantly lower than before work ( $t = 19.52$ ,  $48.13$ ,  $62.03$ ;  $p < 0.05$ ). Every  $1 \text{ mg/m}^3$  increase in welding fumes in the workplace, FVC decreases by 1.02%, and  $FEV_1$  decreases 1.56% compared to pre-employment values (58).

Controlling welding fumes in the workplace is important to avoid health problems. In addition, automotive part welding plant workers had lower  $FEV_1$ ,  $FEV_1/FVC$ , and PEF than non-welding part workers (44). This is in line with research in Nigeria where abnormal pulmonary function parameters significantly reduced all spirometry indices (including  $FEV_1$ , FVC, and  $FEV_1/FVC$ ) in welding workers (35). PEF and maximum flow rates at 50% and 25% of FVC were significantly lower among welding workers than non-welding workers in a Shuaiba industrial area, Kuwait (39).

To reduce risk and minimize the inhalation of welding fumes, companies have to use exhaust that can control the air circulation. The welding fumes taken off could be more quickly diluted by fresh air. Moreover, welding workers can wear welding masks (respiratory) to protect themselves from inhaling welding fumes.

### Limitations of Research

This meta-analysis study has limitations. First, some research articles cannot be analyzed because the available data are inadequate for analysis. Second, some research articles do not present complete statistical data. Third, some articles used designs other than a cross-sectional design. The number of articles obtained is too small. Further studies need to collect more research articles to provide stronger evidence along with measurement methods used for each variable.

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### CONCLUSION

From fifteen articles analyzed, risk of suffering from abnormal pulmonary function is 2.271 times greater for exposure to welding fumes, 2.159 for smoking habit, 1.954 for length of exposure to welding fumes, and 1.491 for use of PPE. The most dominant factor causing abnormal pulmonary function is exposure to welding fumes.

Companies need to control the risk of pulmonary function disorder by applying strict laws and regulations at work, provide PPE kit and technical training on the occupational health and safety, and hold proper orientation sessions on occupational hazards, as well as periodical medical examinations on workers. Workplace must have installation of exhaust that drain polluted air out.

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