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THE IMPACT OF WORKPLACE DUST EXPOSURE AND MASK USAGE ON PULMONARY FUNCTION IN CONSTRUCTION ENVIRONMENTS

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Abstract

Introduction: *The chance of respiratory diseases among workers participating in toll road construction projects is, for example, higher because of non-organic dust. Therefore, this study aims to evaluate the level of lung capacity experienced by the workers by exposing them to dust and wearing masks.* ***Methods:*** *This cross-sectional study investigated toll road projects in Central Java and Yogyakarta and randomly selected workers from different strata of construction companies. The volume Air Sampler estimated dust concentration, while the pulmonary function test included spirometry. All data were analyzed using two-way MANOVA.* ***Results and Discussion:*** *The multivariate analysis of variance showed that workers exposed to dust exceeding the Threshold Limit Value (TLV) had significantly reduced FEV1 and FVC averages ($p < 0.001$). The averages of FEV1 and FVC increased more considerably in mask users than non-users, indicating mask usage's benefits. The decline in lung function was smaller in mask users, with FEV1 (95% CI: 0.080–0.321) and FVC (95% CI: 0.071–0.404). A reduction in walking distance also demonstrated significance to the decrease in FVC.* ***Conclusion:*** *They found that dust in construction declines lung capacity, but wearing masks provides some protection. However, such impact continues even after stopping wearing masks, thus stressing the importance of correct mask usage and staff training. Subsequent research must investigate dust interaction and various types of masks to enhance Indonesian workers' health.*

INTRODUCTION

Dust at the construction site is a major hazard to the respiratory health of construction workers, especially leading to respiratory problems in the construction workforce. Construction site dust can cause one or the following heath complications; asthma or chronic bronchitis, construction workers have been found to have increased respiratory symptoms than workers in other occupational groups (1–3). Second, suspended particulate matter; PM_{10} and $PM_{2.5}$ emanating from construction sites has earlier been known to cause health effects to construction workers and residents living around the sites (4). Globally, construction employees are most susceptible to health diseases caused by dust inhalation. This issue is particularly relevant today, especially in developing countries like Indonesia, where the construction industry has been growing rapidly. According to the Indonesian Contractors Association (5), the construction sector in Indonesia has experienced an annual growth of IDR 423.4 trillion, contributing significantly to the country's economic development.

Inhalation of dust in the workplaces; mineral, organic and chemical, reduce lung capacity. Examples include organic dust found in farming, woodworking and other halls are related to respiratory diseases such as HP, asthma, and COPD (6). Impairment of lung function can be assessed independently of the FEV1 (Forced Expiratory Volume in 1 second) and FVC (Forced Vital

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Capacity). Reduced FEV1 and FVC levels are commonly used as an early sign of the deterioration of the pulmonary health, including bronchitis, COPD, or lung cancer (7–8). Especially in Central Java and the Special Region of Yogyakarta, dust encountered in construction industries threatens the lives of construction workers who themselves have little to no knowledge of the dangers they are exposed to. Research shows that construction work produces large Total Dust Levels with earth-moving tasks taking an average of the 3.85×10^3 μg/m³ (9).

A variety of investigations states that construction trade employees are affected by a resultant decrease in lung function because of exposure to dust. Many constructions workers are exposed to higher dust concentrations, according to studies, and one of the studies observed dust concentration of 1.33 × 10^4 μg/m³ during activities (9). According to the Global Burden of Disease Study, exposure to air at workplace with high Total Dust Levels in construction environment is responsible for 17% of COPD and asthma cases, which in turn claims 519000 lives annually (10). In addition, analysis of cement production workers a material used in construction work and production; annual decrease in FEV1 after exercising was established to be related to increased dust exposure; where a high percentage of lung function deterioration is attributed to occupational dust exposure; recent studies show a direct proportion between Total Dust Levels and respiratory health (11–12). The above findings show that it is crucial to quantify and check the dust concentrations under workplaces to avoid deteriorative effects to the respiratory systems of the employees.

Comparison of construction dust exposure in different countries is influenced by legal requirements, the nature of the dust and the extent to which exposure limits have been set and implemented. While setting the PEL for respirable crystalline silica, developed countries such as United State of America and Australia has adopted a lower limit that is fair compared to the limit fixed in developing countries such as India having 0.150 mg/m³ and China 0.700 mg/m³ (13). Ergotoxicological methodologies highlight the complexity of dust exposure, emphasizing the need for comprehensive assessments that consider various workplace conditions (14). In ergotoxicological methodologies, dust exposure is elaborated to indicate that the overall assessment should comprise a variety of conditions specific to a workplace (15). Survey conducted in South Korea shows the significant problem where construction workers do not wear the mask properly and this increases respiratory illness like cough and shortness of breath. This noncompliance lowers the masks' shielding impact from dust exposure resulting in a higher possibility of Work-Related Respiratory Disease, where failure to adhere to health standards of wearing PPE-N95, is accompanied by a greater change of developing a Work-Related respiratory illness (9). One more Chinese study demonstrated that higher PM_{10} dust concentration in the working environment depends on the diminished lung capacities, including FEV1 as well as FVC. These results substantiate the hypothesis that high exposure to dust at the workplace might reduce the lifespan of workers and therefore cause them to develop some –chronic- diseases (16).

While there have been studies on effects of exposure to dust and effects of protection from the dust by wearing masks separately, there has never been a study that looked into the relationship between dust exposure and mask usage. This suggests that the current literature gap would have other studies encompasses this combined factor which is not well investigated and could be an explanation to the poor health status of construction workers.

Regarding the occupational health in the construction industry in Indonesia, there remains a lack of such studies in contrast to other risk factors. Research conducted in Surabaya compared the lung function behaviour of smoking construction workers who are exposed to dust on the job. Among 45 workers investigated, six workers (66%) experienced reduced lung functioning; four workers had mild obstruction, while two had mild restriction. The measured data of dust level in the project area reflected an average of 1.3452 mg/m³, which is still lower than TLV (17). A study carried out in Depok City aimed at establishing the association between exposure to PM_{10} dust and development of ARI symptoms among construction project workers with 100 respondents. Air quality analysis highlighted that average PM_{10} at project site was 159.43 μg/m³; and ARI reported was 80.8% among workers. To conclude, this research focuses on wearing of Personal Protective Equipment and working environment modification to minimize workers' health hazards (18).

From the current literature review, it is clear that there exists a significant literature that discusses the effect of dust exposure on reduced lung function, effectiveness of masks included but research gaps persist regarding the effect of different Total Dust Levels on the use of masks among construction workers, especially in Indonesia. This study seeks to meet the following objectives so as to fill this gap: To avail appropriate and rich information relative to health and safety in construction site to complement the existing information and lastly, to enhance the general constructive effective health and safety policies in the construction sector.

There are several aspects in which this research is unique to existing literature. First, the focus is on the Indonesian Construction Sector. Most of the earlier studies have focused on some other sectors or some other regions. This study brings into focus the impact of dust exposure on the health of construction workers, a vulnerable and rather unstudied sector; Secondly, emphasis has been placed on the use of masks. This study looks into not only the effects of dust exposure but also the importance of the use of masks as a preventive measure. This research focuses on the context of construction in Indonesia to illustrate the usefulness of mask use and provide evidence that can assist in improving occupational health measures.

To this end, this study seeks to investigate effects of dust exposure and mask wearing among toll road construction workers on their lung function. This study hypothesis shall, therefore, be that increased dust exposure in the workplace is inversely proportional with FEV1 and FVC values, a situation that can be prevented through the use of masks. Employing construction workers in Klaten, Boyolali, and Sleman districts, this research will effectively contribute to the existing body of knowledge concerning health consequences of inhaling construction site dust and significance of protecting oneself via mask wearing in construction business. The study findings will also provide the necessary information to create improved health and safety policies within the construction industry in Indonesia.

METHODS

In this research, the survey approach is cross-sectional to determine the impact of airborne dust at the workplace and wearing of masks on lung capacity as indicated by FEV1 and FVC. Cross-sectional study design is appropriate for this study since it enables the determination of the correlation between exposure to dust, wearing of masks and lung capacity in a particular time. While this design cannot investigate causal associations, it gives important comprehension on how the deterioration of lung function is distributed among the construction workers of toll roads in Central Java and the Special Region of Yogyakarta. Thus, by comparing the workers having different dust exposure levels and those wearing mask/non-masking workers, some relations can be defined which could be useful for producing suggestions for future prospective studies and protection measures.

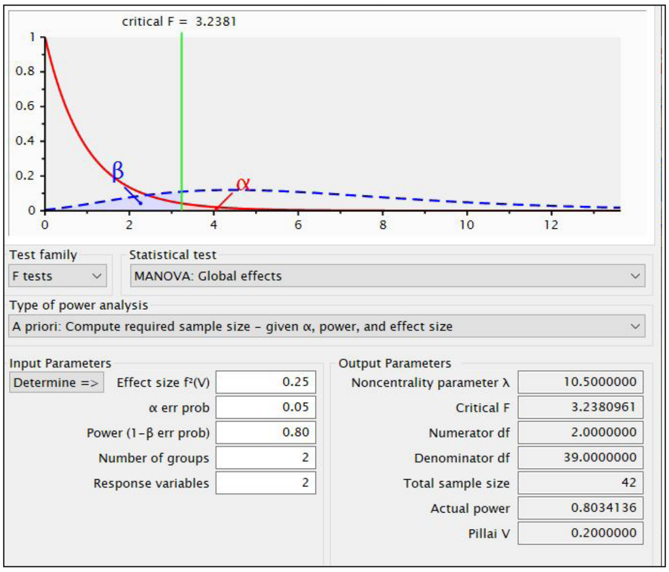

Figure 1. Minimum Sample Calculation Using G*Power Software

The study population comprises all construction workers from construction sites of toll road construction projects in Central Java (Klaten and Boyolali) and the Special Region of Yogyakarta (Sleman). The criteria for selection of participants are the workers who have served for more than six months in the toll road construction, willing to participate after being informed about the study, and had no history of chronic lung diseases like TB, severe asthma which may influence the findings of the examination. Exclusion criteria include workers who had acute lung disorder during examination and workers who cannot do spirometry rightly.

The sample was taken using a stratified random sampling technique, where workers were grouped based on two independent variables: Dust Levels (categorized as >TLV and <TLV) and mask compliance (categorized as compliant and non-compliant). The strata were defined based on specific factors such as job location, including zones (Zone 1: work near the dust source, such as excavation and compaction areas; Zone 2: work away from the dust source, such as paved areas) and job roles (Role 1: field workers involved in excavation, soil compaction, and asphalting; Role 2: workers in more protected areas but still on-site, such as heavy equipment maintenance workers and supervisors who frequently visit work areas). The minimum sample size was estimated using G*Power software with α error probability of 0.05, Power (1- β error probability) of 0.80 and medium Effect size f of 0.25. Total Dust Levels and Mask Usage had two groups – the control group and the intervention group, while Total Dust Levels and Mask

Usage had two dependent variables; FEV1 and FVC. Figure 1 shows the results of the calculations that has been made using G*Power for the MANOVA test.

However, using the information presented in Figure 1, the minimum sample size to be attained is approximately 42. Because this study will work with 2 groups, the minimum number of populations will be 42 x 2 = 84. In order not to encounter high sample loss while analyzing the data, the sample size is determined to be 30% larger than the minimum needed, 84 + 25.2 = 109.2, thus 110 subjects.

The Operational Definition of the Dust Exposure variable is the dust intensity in milligrams per cubic meter (mg/m³) in working environment. Dust exposure data is categorized into two groups: the particles which are produced above the threshold limit (> 10 mg/m³) and those that are produced at or below the threshold limit (≤ 10 mg/m³). Mask Usage is hereby operationalized as the extent to which workers putting on a mask when working. Mask usage data is classified into two categories: compliant which means wearing appropriate personal protective item particularly a face mask and non- compliant which is not wearing the face mask or wearing and substandard face mask. Lung Function is measured by two parameters: FEV1 as the volume of air expelled during forced exhalation during the first second of the process, and FVC as the volume of air expelled at the culmination of a forced exhalation. Both FEV1 and FVC are measured in liters, which are quantitative data.

The total dust concentration in workplace is determined using high volume air sampler model of TFIA-2F which is calibrated by testing laboratory no LK-193-IDN Ministry of Environment and Forestry, calibration number K-211/KAL/PSIKLH/04/2022. Mask usage compliance is assessed by means of a survey and a field observation form. Pulmonary function tests in which FEV1 and FVC are estimated are carried out using a Chest Graph HI-105 Spirometer. All the FEV1 and FVC measurements are provided to a doctor awarded with the certificate by the Ministry of Manpower as an occupational health doctor, and their comparison is made. The survey of mask usage compliance is done by self-administered questionnaires given to the respondents. Dust exposure quantitative variable is determined by obtaining air samples at the worksite during working time with a High-Volume Air Sampler; the mask use qualitative variable is assessed by respondents' answers to the questionnaire, which includes frequency and compliance with mask use, as well as a field observation checklist.

Collected data are statistically tested by Two-Way MANOVA to determine the influence of exposure to dust and wearing of masks on lung capacity (FEV1 and FVC). Two-Way MANOVA formula :

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ij}$$

Explanation:

Y_{ij} : The value of the dependent variable (FEV1 and FVC) for group I and j.

μ : The overall mean (grand mean) of all observations.

α_i : The effect of the first factor (dust exposure), where i represents the level of the factor (high and low exposure).

β_j : The effect of the second factor (mask usage), where j represents the level of the factor (compliant and non-compliant mask use).

$(\alpha\beta)_{ij}$: The interaction effect between dust exposure and mask usage. This measures whether the effect of dust exposure on lung capacity differs depending on the level of mask usage.

ϵ_{ij} : The error or random variance that cannot be explained by the model.

The analysis is conducted using the SPSS software. We use a significance level of α = 0.05 in all tests.

The Two-Way MANOVA test too followed several steps. First, the data were normalized and verified to ascertain appropriateness of measures used in cleaning techniques such as managing any missing data and some outliers. After that, assumption testing was carried out to validate the use of the developed and used empirical model. The nonparametric test for dependence of the normality of the residuals was not rejected for FEV 1 and FVC (e.g., for FEV 1, ZRE 1, yielded p = 0. 120). Similarity of variances of the independent variables with the groups was checked via Levene's test while the independence factor was upheld throughout the study. Means and standard deviations were also employed to present the study sample details, as well as frequencies and distributions for categorical variables.

After all assumptions were fulfilled, the Two-Way MANOVA was conducted to compare the results of dust exposure and mask usage on lung capacity with Type of mask as a within subject factor and examining the main effects of between subject factor Type of work and interaction effects between all factors. When the results reached significance, post hoc comparisons were also used in an effort to determine exact differences between groups. Through this multistage cross-sectional survey approach, a check was performed to confirm reliable estimates of the associations between the variables.

These steps were carried out using SPSS software, with a significance level set at α = 0.05 for all statistical tests. This study has obtained ethical clearance approval from Dr. Moewardi Hospital in Surakarta, as evidenced by the issuance of ethical clearance letter number: 1. Ref no: 042/IV/HREC/2024 dated: April 29, 2024.

RESULTS

Hence several classical assumptions is required when carrying out Two-Way MANOVA analysis. Classical tests have been applied to these data in terms of checking the assumption of normality for instance, we have used the Kolmogorov-Smirnov method on the Standardized Residual data for FEV1 (ZRE_1) gave p = 0.120 > 0.05 hence such a data is normally distributed. Furthermore, using the Standardized Residuals data for FVC we obtained ZRE_2, the p-value of 0.317 (p > 0.05) reaffirms the normal distributions of the data in the study. Therefore, the assumption of normality is holds as true for this sets of data.

The second classical assumption test is the Homogeneity of Variance-Covariance assumption, that can be tested using Box's M Test. M test in the Box resulted in a p-value of 0,132 which as it is higher than 0,05 shows that the assumption of equal covariance matrices has been met. The third of the classical test that checks for the assumption is the Homoscedasticity test, checked with Levene test on each dependent variable. The Levene's Test of Equality of Error Variances was also carried out for both FEV1 and FVC; both were greater than 0.05, p-Value = 0.775 for FEV1, p = 0.501 for FVC, therefore the assumption of homogeneity of variance of FEV1 and FVC is fulfilled. The fourth classical assumption test is the Multicollinearity assumption and checks the correlation between FEV1 and FVC on Pearson Product-Moment basis. For the current study, the obtained correlation coefficient was r= 0.469, and because r<0.8 the assumption of multicollinearity was met. Since all these assumption tests have been met, the analysis can go ahead with Two-Way MANOVA.

In this study, FEV1 (Forced Expiratory Volume in the First Second) and FVC (Forced Vital Capacity) measurements were compared based on the dust concentration in the workplace, categorized into two groups: Total Dust Levels where the exposure was above the TLV and the exposure level below the TLV. The mean FEV1 and FVC, SE and 95CI values were calculated and are depicted in Table 1.

Table 1. Mean FEV1 and FVC Based on Dust Concentration in the Workplace

Variable	Total Dust Level	Mean	Std. Error	95% Confidence Interval
FEV1	> TLV	2.354	0.046	2.264 to 2.444
	< TLV	2.815	0.040	2.735 to 2.895
FVC	> TLV	2.777	0.063	2.653 to 2.901
	< TLV	3.374	0.056	3.264 to 3.484

Note: TLV = Threshold Limit Value; FEV1 = Forced Expiratory Volume in the First Second; FVC = Forced Vital Capacity

In an endeavor to test the impact of dust concentration on the lung function, the authors conducted the multivariate testing taking FEV1 and FVC as the dependent variables. From the multivariate tests such as Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, all show a significant effect for dust concentration on both the variables. Presented in Table 2 are the detailed results of the multivariate tests used in this study.

Table 2. Results of Multivariate Tests Based on Dust Concentration in the Workplace

Statistics	Value	f	Hypothesis df	Error df	p-Value	Partial Eta Squared
Pillai's Trace	0.473	47.097	2	105	<0.001	0.473
Wilks' Lambda	0.527	47.097	2	105	<0.001	0.473
Hotelling's Trace	0.897	47.097	2	105	<0.001	0.473
Roy's Largest Root	0.897	47.097	2	105	<0.001	0.473

Note: The results of the multivariate analysis indicate a significant effect of Total Dust Level on FEV1 and FVC, with a significance level of p < 0.05

Mean comparison of FEV1 and FVC was made in order to compare the groups of workers with higher and lower dust exposure than the TLV. As illustrated in Table 2, the results of comparison revealed a higher mean in the experimental group than that of the control group with a mean difference presented in Table 3.

Table 3. Comparison of Mean FEV1 and FVC Based on Dust Concentration in the Workplace

Variable	Total Dust Level(I)	Total Dust Level(J)	Mean Difference (I-J)	Std. Error	p-Value	95% Confidence Interval
FEV1	> TLV	< TLV	-0.461*	0.061	<0.001	-0.582 to -0.340
	< TLV	> TLV	0.461*	0.061	<0.001	0.340 to 0.582
FVC	> TLV	< TLV	-0.597*	0.084	<0.001	-0.763 to -0.431
	< TLV	> TLV	0.597*	0.084	<0.001	0.431 to 0.763

*Note: TLV = Threshold Limit Value; *p < 0.05 indicates a significant difference.*

Apart from dust concentration, this study also analyzed FEV1/FVC<pairwise comparison>depending on the mask use of construction workers. Table 4 presents the mean FEV1 and FVC and confidence intervals in the compliant and non-compliant mask-wearing groups with their standard error.

Table 4. Mean FEV1 and FVC Based on Mask Usage

Variable	Mask Usage	Mean	Std. Error	95% Confidence Interval
FEV1	Non-compliant	2.484	0.044	2.397 to 2.572
	Compliant	2.685	0.042	2.602 to 2.768
FVC	Non-compliant	2.957	0.061	2.836 to 3.077
	Compliant	3.194	0.058	3.080 to 3.308

Note: FEV1 = Forced Expiratory Volume in the First Second; FVC = Forced Vital Capacity

Variable analysis was done to compare the effect of masks on FEV1 and FVC. The findings show in Table 5 that the use of masks significantly predicted both the variables at $p < 0.05$.

Table 5. Results of Multivariate Testing Based on Mask Usage

Statistic	Value	f	Hypothesis df	Error df	p-Value	Partial Eta Squared
Pillai's Trace	0.136	8.251	2	105	<0.001	0.136
Wilks' Lambda	0.864	8.251	2	105	<0.001	0.136
Hotelling's Trace	0.157	8.251	2	105	<0.001	0.136
Roy's Largest Root	0.157	8.251	2	105	<0.001	0.136

Note: The multivariate test results showed a significant effect of mask usage on FEV1 and FVC with p < 0.05.

The average FEV1 and FVC was also compared according to the extent of compliance with wearing of the masks. The systematic results indicate there are disparities between complied and non-complied worker involving face masks, as highlighted in Table 6.

Table 6. Comparison of Average FEV1 and FVC Based on Mask Usage

Variable	Mask Usage (I-J)	Mean Difference (I-J)	Std. Error	p-Value	95% Confidence Interval
FEV1	Non-compliant	-0.201*	0.061	0.001	-0.321 to -0.080
	Compliant	0.201*	0.061	0.001	0.080 to 0.321
FVC	Non-compliant	-0.238*	0.084	0.005	-0.404 to -0.071
	Compliant	0.238*	0.084	0.005	0.071 to 0.404

*Note: *p < 0.05 indicates a significant difference.*

DISCUSSION

Therefore, based on the results of the present research, it can be said that the research hypothesis that is associated with a direct relationship between workplace dust exposure and FEV and FVC reduction is well supported. These results show that workers engage in construction work have lower FEV1 and FVC if they are exposed to Total Dust Levels, which are above the TLV as compared to those exposed to Total Dust Levels below the TLV. The pre and post values of FEV1 and FVC have a decline and indirectly infers the sign of dangerous impairment of lung function; it again stresses that dust control needs to be implemented in work setting (19–20). In addition, the present research also supports the use of masks as an effective measure against the deadly virus in order to prevent workers' lung health. Comparing FEV1 and FVC of the participants who had worn the masks throughout their working shift with the ones who did not wear masks, the results showed that the mask use reduces the adverse impacts of dust on respiratory health. With such empirical evidence, there is a need to increase awareness on construction workers on the need to wear face mask and other protective measures.

Airborne dust in the construction industry effects lung function biologically in several way (21). Particles inhaled can reach the lower respiratory tract even the alveoli and provoke inflammation (22). These mechanisms include: 1) Inflammatory Response. When the dust particles remain in the alveoli, they trigger immune cells like macrophages to release cytokines and mediators that leads to fighting off foreign bodies. However, long-term exposure can lead to chronic inflammation, damaging lung tissue and reducing its elasticity (23–24); 2) Tissue Damage. Inhalation of dusts provokes scarring (fibrosis) due to ongoing injury to cells and diminished lung function and FEV1/FVC (25–26); 3) Oxidative Stress: Dust induces the generation of free radicals, which induce oxidative stress and damage cells and promote inflammation (25,27–28); 4) Specific Lung Diseases. Exposure to certain dusts, such as silica, can lead to silicosis, characterized by fibrosis and progressive decline in lung function, as well as increasing the risk of chronic obstructive pulmonary disease (COPD) and lung cancer (29).

One of the best ways for reducing dust particle contamination in a workplace is to use masks as they can filter 61.4%–99.2% depending on their design and materials (30). The purpose of masks is to prevent harmful particles from entering the respiratory system (31). Masks Protect Workers through the following measures: 1) Physical Filtration. This means that a mask with significant filtration standard (i.e., N95) can filter out small dust particles or act as barrier against dust, smoke and other microparticles (32–33); 2) Revent Inhaling Hazardous Particles. Properly worn masks should have tight seals to skin around the nose and mouth, in which they inhale only air passed through the mask filter reducing exposure risk from inhalation of substances/dust/particle even it is not filtered by such particular respirator. Use of masks can increase FEV1 and FVC among workers exposed to dust (34); 3) Decreasing the Risk of Respiratory Diseases, Masks reduce the inhalation exposure level by fresher during working hours. It also means one less inhale that makes a contribution towards long-term lung disease risk. The use of mask has become an important part in health protocols at construction site (9,31); 4) Knowledge and Compliance, Training program required through training to improve the awareness of workers by using masks which is useful for respiratory akan healthy transition have idea with dust wear disease encountered at working place.

While masks are one way to reduce worker exposure to inhalable dust particles in the environment, they may not always be used correctly (35). Correct usage and fit are essential to reduce exposure; inappropriate utilization, such as using a mask with an inadequate filtering face piece leading to leakage at the seal, may expose users unnecessarily, diminishing its protective effect (36–37). Among the types of masks, N95 respirators have been found to offer the best protection against fine particulate matter commonly found in construction environments, including toll road projects. However, the effectiveness of masks is highly dependent on correct usage, ensuring a proper fit, and regular maintenance. Despite their benefits, masks can hinder communication and limit breathing, potentially leading to other health and safety issues (38). In the end, an integrated dust prevention method, including the use of appropriate masks, along with administrative and engineering controls seem to be more effective in addressing all vectors of exposures both qualitatively and quantitively (39–41).

In the field of occupational medicine, several investigations in different parts of the world have analyzed the relationship between lung function and exposure to dust, as well as the possibility of risk reduction through the use of masks. This paper advances the state of the art in the current body of literature by providing a closer insight in the construction sector in Indonesia which has largely been neglected. Below is a how the objectives of the study of this study and objectives of similar ones in other country compare: 1) In the Burden of Obstructive Lung Disease (BOLD) study which was carried out in a number of countries including Albania, Algeria, Australia, Austria, Bangladesh, Trinidad and Tobago, Tunisia, Turkey, UK and USA, correlation between respiratory symptoms and lung functions with type of occupation was established (42). In Norway, it was found that high dust levels among unmasked workers reduce lung functions; Emphasizing the need for protective measures although, over time, there are still dangers to the lungs, even with the use of a mask (43). These findings are consistent with the findings of this study, which also suggests that the wearing of mask can mitigate the risks, though the reduction of the function of the lung continues to take place among dust imposition employees on a chronic basis; 2) Studies done in Australia revealed that following mask requirements can avert up to 60% of lung function impairment caused by exposure to silica dust (44). This research is in support of the findings in this study, which show that masks do protection but it is more effective when the right type of masks are used and used appropriately; 3) In a study conducted in Ethiopia it was discovered that workers who did not have any form of respiratory protection, experienced more respiratory symptoms than those who wore masks (45–46). This observation confirms the findings in this study which states that in vast majority of instances, masks used by construction workers in Indonesia do prevent respiratory complaints.

Several limitations can be identified in this study. Firstly, the design is cross-sectional; hence, it represents only a simple relationship between exposure to dust and lung function, not causality; therefore, it cannot firmly establish the impact of long-term dust exposure. While several variables are considered, there are still other factors not investigated in-depth, such as health history, exposure to other hazardous substances, and environmental ones that might present some bias and affect the generalization of these findings. Third, it may not be representative of the whole population of Indonesia's construction workers, as demographic characteristics may differ in other regions with probably different working conditions. The results of the present study, therefore, have to be judged cautiously, and the policy recommendations that are formulated need to have their relevance tested in wider research concerning disparate contexts. These findings do not at all diminish the contribution this present research makes toward an understanding of the effect of dust exposure on the health of construction workers and a call for more research.

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AUTHORS' CONTRIBUTION

All authors actively participated in this study and take equal responsibility for the contents of the article. Contributions of the individual authors are as under: S: Conceptualization, Methodology, Software; MPW: Data curation, Writing-Original draft preparation; FSNS: Visualization. BC: Investigation. RW: Software, Validation. RPF: Data description, Manuscript revision. YRA: Analysis and Visualization. YDP: Manuscript Review. RAA: Manuscript Editing. All authors have read and approved the final version of this manuscript.

CONCLUSION

This study focused on the impact of dust exposure in toll-road construction workplaces on the lung function of workers. The findings demonstrate that exposure to dust significantly reduced lung function, while the use of masks effectively mitigated some of the risk. However, long-term dust exposure still contributed to a decline in lung function. These results are consistent with international studies, which highlight the importance of proper mask selection and training. Future research in Indonesia should focus on improving health protection for construction workers, particularly through longitudinal studies to assess the cumulative effects of dust exposure and to evaluate the effectiveness of different types of masks.

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