ORIGINAL ARTICLE

INTERLEUKIN-8 AND LUNG FUNCTION DISORDERS AMONG MARBLE ARTISANS IN TULUNGAGUNG, INDONESIA

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ABSTRACT
Exposure to marble dust containing crystalline silica is a serious occupational health problem among marble artisans. Silica exposure may trigger inflammatory responses in the respiratory tract and can contribute to lung function disorders. Inflammatory responses in previous studies have been characterized by increased levels of Interleukin-8 (IL-8). However, evidence linking IL-8 to impaired lung function remains limited in Indonesia. This study aimed to analyze differences in IL-8 levels based on complaints of shortness of breath among marble artisans in Tulungagung. A cross-sectional study was conducted on 30 marble artisans. Dust exposure (total dust, respirable dust, and silica) was measured using a Personal Dust Sampler, while IL-8 levels were analyzed using the ELISA method. Data were analyzed using non-parametric tests. Most respondents were >45 years old, had ≥5 years of work experience, and used Personal Protective Equipment (PPE) only occasionally. The finishing unit recorded the highest exposure level and exceeded the Threshold Limit Value (TLV), while respirable dust levels at all three locations were below the threshold. Statistical analysis showed significant differences in IL-8 levels based on PPE usage frequency (p = 0.008), silica exposure (p = 0.025), and shortness of breath complaints (p = 0.003). In contrast, IL-8 levels did not differ significantly based on respirable dust exposure (p = 0.885) or work duration (p = 0.758), and no correlation was found between IL-8 levels and age (p = 0.065). Elevated IL-8 levels were associated with shortness of breath complaints, reinforcing its role as a biomarker of inflammation and impaired lung function. These findings highlight the importance of routine IL-8 monitoring, ensuring the availability of standard-compliant PPE, and improving worker adherence to prevent the risk of respiratory function impairment.

Keywords: *IL-8, lung function disorders, marble artisans, respiratory complaints, silica dust.*

INTRODUCTION

Respirable dust has long been recognized as a major determinant of respiratory disorders and a significant contributor to the global burden of occupational diseases. Particles within the respirable fraction, typically ranging from 0.5 - 4 micrometers in diameter, are capable of bypassing the upper airway defenses and depositing in the lower respiratory tract, thereby increasing the risk of pulmonary impairment (SNI 7325, 2009)[1]. Environmental and public health experts emphasize that particles smaller than 2.5 micrometers are particularly hazardous, as they can penetrate deeply into the respiratory system and trigger adverse health effects. Prolonged exposure to such irritant agents may lead to occupational lung diseases, including silicosis and Chronic Obstructive Pulmonary Disease (COPD), with the severity influenced by the type and concentration of dust, duration of exposure, and the amount of dust[2]. Globally, occupational lung diseases remain a major health burden, with millions of workers exposed to respirable dust and crystalline silica each year. Reports from the World Health Organization (WHO) and the International Labour Organization (ILO) indicate that silicosis, COPD, and other dust-related disorders contribute substantially to occupational morbidity and mortality. In Indonesia, cases of pneumoconiosis and silica-related respiratory diseases are still underreported, yet workers in industries such as mining and marble processing face particularly high risks.

Marble, classified as a sedimentary rock from the sandstone group. During cutting, grinding, and finishing processes, marble generates respirable dust that contains a high proportion of crystalline silica (>95%)[3]. Tulungagung, East Java, is the largest marble production center in Indonesia, employing thousands of artisans who are continuously exposed to this hazard. Previous studies in industries such as wood processing, pulp and paper, and drilling have demonstrated strong correlations between dust exposure and inflammatory biomarkers[4-6]. Exposure to irritant agents such as dust can accumulate in the lungs and may lead to both acute and chronic occupational lung diseases. The likelihood of developing these health problems can be exacerbated by factors such as poor compliance with the use of Personal Protective Equipment (PPE), older age, and longer duration of exposure[7].

Research by Widajati highlighted significant associations between silica dust exposure, elevated interleukin-13 (IL-13) levels, and pulmonary function disorders in workers, underscoring the role of interleukins as cytokines that regulate inflammation and immune responses[8]. In addition to IL-13, interleukin-8 (IL-8) has been identified as a pro-inflammatory chemokine that recruits neutrophils to lung tissue. As a member of the α-chemokine family, IL-8 drives neutrophil infiltration into lung tissue, where they release proteolytic enzymes that damage lung elasticity[5]. Therefore, IL-8 has the potential to serve as an early biomarker of impaired lung function in high-risk groups such as marble artisans[9].

Empirical evidence from various studies supports the role of IL-8 as an inflammatory biomarker and an early indicator of impaired lung function. Previous studies have demonstrated that IL-8, together with IL-33 and IL-10, contributes to pulmonary fibrosis by activating macrophages[9]. Clinical research reported elevated IL-8 levels associated with chemokine activity, serving as an early marker of COPD progression[10]. IL-8 levels are known to increase in wood industry workers and are associated with respiratory complaints[5,11]. In COPD patients, IL-8 concentrations were elevated compared to healthy individuals[12]. In addition, research by Widajati (2023) highlighted that individual characteristics (such as age, nutritional status, and work duration) and dust exposure levels exert a highly significant impact on lung function[13].

These findings confirm that elevated IL-8 levels are closely associated with impaired lung function, including COPD and shortness of breath complaints among high-risk populations exposed to occupational dust. This evidence is particularly relevant for marble artisans, whose work environment involves high levels of silica-containing dust. However, cross-industry studies have shown mixed results, a study conducted among pulp and paper mill workers demonstrated a positive association between inhalable dust exposure and serum IL-8 levels[4]. Meanwhile, studies on workers, stone drillers exposed to crystalline silica reported a negative association with IL-8 concentrations[6]. These contrasting findings suggest that the mechanisms underlying IL-8 elevation in response to dust exposure remain complex and may be influenced by the type of industry, characteristics of the particles, and individual factors.

To date, most studies have focused on the correlation between dust exposure and lung function disorders, such as COPD and fibrosis. Studies that directly examine the causal factors of IL-8 elevation among marble industry workers in Indonesia remain limited. This knowledge gap is significant, as marble artisans are continuously exposed to high concentrations of dust in their work environment. Therefore, this study aims to analyze differences in serum IL-8 levels based on pulmonary function disorders (shortness of breath complaints), as well as to identify other risk factors associated with elevated IL-8 levels among marble artisans in Tulungagung, Indonesia. The findings of this study are expected to serve as a theoretical basis and support occupational health policies, including biomarker monitoring programs for IL-8 levels as an early indicator of inflammation and impaired lung function.

METHODS

This study employed an observational cross-sectional design to examine differences in interleukin-8 (IL-8) serum levels based on lung function disorders (shortness of breath complaints) experienced by marble artisans in Tulungagung, East Java, and to analyze risk factors associated with elevated IL-8 levels. The study population consisted of production workers who met the inclusion criteria, which required participants to be in good health and free from any prior asthma or chronic respiratory diseases. The sample size was calculated using the Slovin formula, resulting in 30 workers selected through simple random sampling. Ethical approval was obtained prior to data collection under clearance number 064/HRECC.FODM/II/2022.

Data collection involved both biological sampling, workplace environmental measurements, and structured interviews. IL-8 levels were analyzed using the Enzyme-Linked Immunosorbent Assay (ELISA), a technique recognized for its high sensitivity and specificity in detecting cytokines. Respirable dust exposure was measured using personal dust samplers (mg/m^3), which were worn by workers throughout their shifts to capture real-time airborne particulate concentrations. Meanwhile, silica dust concentrations were quantified (mg/m^3) through X-Ray Diffraction (XRD) using the NIOSH 7500 standard. Information on individual characteristics, including age, work duration, smoking behavior, and respiratory complaints obtained through a questionnaire. Data on shortness of breath complaints and the frequency of Personal Protective Equipment (PPE)

Table 1: Distribution of characteristics of marble artisans in Tulungagung

Category	n	%
Age		
26 – 35 years	5	16.7
36 – 45 years	9	30.0
>45 years	16	53.3
Work Periods		
< 5 years	11	36.7
≥ 5 years	19	63.3
Length of Work		
≤ 8 hours	19	63.3
> 8 hours	11	36.7
PPE Use		
Never	3	10.0
Occasionally	18	60.0
Consistently	9	30.0
Respiratory Complaints		
No	16	53.3
Yes	14	46.7
Smoking Behavior		
No	17	56.7
Yes	13	43.3

use were self-reported, with PPE usage categorized as 'Never,' 'Occasionally,' or 'Consistently.' The validity of the questionnaire items was developed based on literature reviewed by experts and a limited pilot test to ensure question clarity.

For statistical analysis, univariate analysis was performed to summarize participant characteristics and exposure respirable dust and silica dust levels using frequency distribution tables. Normality testing of IL-8 levels was conducted using the Kolmogorov-Smirnov test, which indicated that the data were not normally distributed ($p<0.05$). Consequently, non-parametric methods were applied in the bivariate analysis. The Spearman correlation test was used to assess the strength and direction of associations between continuous and ordinal variables (such as the age variable). The Mann-Whitney U test was employed to compare differences in IL-8 levels between two independent groups (e.g., silica dust, work duration, and shortness of breath complaints), while the Kruskal-Wallis test was applied for comparisons involving more than two groups, including respirable dust concentration and frequency of PPE use.

RESULTS

Descriptive Analysis

The results of the descriptive analysis of marble artisans in Tulungagung revealed several important findings (Table 1).
Based on Table 1, more than half of the respondents (53.3%) were older than 45 years, with work experience of ≥5 years (63.3%), suggesting the possibility of considerable cumulative dust exposure in the workplace. Most respondents reported working ≤8 hours per day. In terms of protective behavior, the use of Personal Protective Equipment (PPE) was suboptimal. This was identified from the fact that the majority of workers used PPE only occasionally. In addition, most workers were also found to have smoking habits, which are generally known to pose risks to the respiratory system and lung function. More than half of the workers (53.3%) self-reported complaints of shortness of breath.

The majority of workers (36.7%) were found to be exposed to particulate matter concentrations of 37.1203 mg/m^3 in the finishing unit (Table 2). Meanwhile, measurements of respirable dust levels at all three study sites remained below the Threshold Limit Value (TLV) of 3 mg/m^3, with the finishing unit recording the highest level at 0.8819 mg/m^3 compared to the other units. Even when respirable dust concentrations remain below regulatory thresholds, chronic and long-term exposure still poses a risk of pulmonary impairment, particularly among vulnerable groups.

Table 2: Distribution of total dust content and respirable dust levels based on worker locations

Locations	Dust level (mg/m^3)	Respirable dust levels (mg/m^3)	n	%
Polishing	0.1786	0.4751	11	36.7
Sawing	0.5488	0.4879	8	26.7
Finishing	37.1203	0.8819	11	36.7
Total			30	100.0

Table 3: The concentration of silica based on the location of Tulungagung marble artisans

Locations	Silica content (mg/m^3)	n	%
Polishing	0.0981	11	33.3
Sawing	0.0981	8	26.7
Finishing	0.1114	11	40.0
Total		30	100.0

Table 4: Interleukin-8 difference test based on work duration

Work Duration	n	Mean ± SD	Mean Rank	Mann-Whitney U Test		
				Mann-Whitney U	Z	p
<10 Year	20	282.94 ± 261.636	15.15	93.000	-0.308	0.758
≥10 Year	10	273.42 ± 220.977	16.20			

Table 5: Results of the difference test of interleukin-8 (IL-8) levels based on respirable dust concentration

Respirable Dust	N	Mean ± SD	Mean Rank	Kruskall Wallis Test	
				x^2	p
0.4751	11	169.58 ± 54.958	12.86	5.014	0.082
0.4879	8	238.47 ± 223.331	12.63		
0.8819	11	419.99 ± 315.886	20.23		

Based on the results of silica dust measurements in Table 3, the majority of respondents were exposed to silica concentrations of 0.1114 mg/m^3 in the finishing unit and 0.0981 mg/m^3 in the polishing unit. All three measured concentrations exceeded the TLV for silica recommended by NIOSH and the provisions of Minister of Manpower Regulation No. 5 of 2018, which is 0.025 mg/m^3. The highest burden was observed among workers in the finishing unit, who were exposed to the greatest silica concentrations.

Bivariate Analysis

Based on the results of Spearman's correlation test, a correlation coefficient of 0.341 was obtained with a significance value of $p > 0.05$. This indicates that there is no statistically significant relationship between age and IL-8 serum levels among workers. Although the coefficient shows a weak positive relationship, where increasing age tends to be followed by an increase in IL-8 levels. The relationship is not strong enough to be considered statistically significant.

Table 4 shows that based on the Mann-Whitney U Test, the p-value was > 0.05, indicating that there is no statistically significant difference in IL-8 serum levels between workers with <10 years and ≥10 years of work duration. Based on the z-value of −0.308 and the mean rank values, there is an indication that the <10-year work duration group (15.15) tends to have lower IL-8 levels than workers with ≥10 years of work duration (16.20), but the difference is very small and not statistically significant.

The results of the analysis presented in Table 5 show the Kruskal–Wallis test results indicating that there was no difference in IL-8 levels based on respirable dust concentrations ($x^2 = 5.014$; $p = 0.082$). This finding indicates that interleukin-8 (IL-8) levels in the blood serum of marble artisans are not influenced by the respirable dust concentrations received at the workplace. There is a tendency for IL-8 levels to decrease in groups with lower respirable dust exposure, but the differences between groups are not statistically significant. The non-significant results may be due to lower exposure levels, differences in dust composition, and variability in individual susceptibility.

Table 6: Results of interleukin-8 level comparison based on PPE use

PPE Use	N	Mean ± SD	Mean Rank	Kruskall Wallis Test	
				x^2	p
Never	3	708.69 ± 465.271	27.00	9.577	0.008
Occasionally	18	269.31 ± 186.577	16.58		
Consistently	9	157.72 ± 59.163	9.50		

Table 7: Results of interleukin-8 (IL-8) level comparison based on shortness of breath complaints

Complaints of Shortness of Breath	n	Mean ± SD	Mean Rank	Mann-Whitney Test		
				Mann-Whitney U	z	P
No	16	162.49 ± 54.060	10.97	39.50	-3.015	0.003
Yes	14	413.80 ± 307.006	20.68			
Silica Dust Concentration	**N**	**Mean ± SD**	**Mean Rank**	**Mann-Whitney U**		
				Mann-Whitney U	**z**	**p**
0.0981	19	198.58 ± 149.317	12.76	52.500	-2.238	0.025
0.1114	11	419.99 ± 315.886	20.23			

The results of the Mann-Whitney U test presented in Table 7 show a z-value of -3.015 with a p-value of 0.003.These results indicate that there is a difference in interleukin-8 (IL-8) levels in the blood serum of marble artisans based on shortness of breath complaints. Workers who reported shortness of breath had significantly higher mean rank IL-8 levels (20.68) compared to those without such complaints (10.97). These results suggest that respiratory complaints are closely related to increased IL-8 levels, reinforcing the role of IL-8 as a biomarker of airway inflammation. The finding also highlights that marble workers experiencing respiratory symptoms may already be undergoing inflammatory processes that predispose them to chronic respiratory diseases.

The results of the Mann-Whitney U test presented in Table 8 show a z-value of -2.238 with a p-value of 0.025. This finding indicates that there is a difference in interleukin-8 (IL-8) levels in the blood serum of marble artisans in Tulungagung based on the silica dust concentrations they were exposed to. Workers exposed to higher silica dust concentrations (0.1114 mg/m^3) showed higher mean rank IL-8 levels (20.23) compared to those exposed to lower concentrations (12.76). This indicates a tendency for IL-8 levels to increase with higher silica dust exposure.

DISCUSSION

Based on the results of this study, all respondents exhibited detectable levels of IL-8 in their blood, ranging from 35.734 - 1133.899 ng/L. IL-8 is a pro-inflammatory cytokine that plays a critical role in mediating and amplifying inflammatory responses. Elevated IL-8 can promote neutrophil infiltration in the airways, particularly in individuals with asthma, leading to airway remodeling, obstruction, and consequent reductions in lung function[14]. Variations in IL-8 levels may be influenced by allergens dan iritan lain present in the workplace environment[15].

Respirable Dust and Silica Dust Factors

The Threshold Limit Values (TLVs) established in the Regulation of the Minister of Manpower No. 5 of 2018 specify permissible exposure limits of 10 mg/m^3 for total dust and 3 mg/m^3 for respirable dust [16]. Real-time measurements in this study revealed that total dust concentrations exceeding the TLV were observed only in the finishing section, with levels reaching 37.12 mg/m^3. In contrast, respirable dust measurements indicated that none of the workers were exposed to concentrations exceeding the established threshold limits.

Despite these findings, exposure levels below the TLVs should not be considered entirely safe. Inhaled dust particles can accumulate in the respiratory tract over time and may lead to progressive impairment of lung function. Fine particulate matter, particularly particles smaller than 1 µm, poses a greater health risk because of its ability to penetrate deeply into the alveolar region. Conversely, ultrafine particles smaller than 0.1 µm tend to be inhaled and exhaled without significant deposition in the lungs. These observations highlight the importance of continuous dust exposure monitoring and the implementation of effective preventive measures to safeguard workers' respiratory health.

The exposure to particulate matter such as PM_{10} and $PM_{2.5}$ has been consistently associated with an increased risk of respiratory symptoms [17]. Long-term occupational exposure, particularly over periods of 5–20 years, is known to substantially elevate the risk of adverse health effects related to crystalline silica. Therefore, the findings of this study emphasize the need for decision-makers to implement comprehensive risk management strategies to prevent the long-term health consequences of silica exposure in the workplace [18].

Evidence from cement industry workers demonstrates that chronic exposure to respirable silica, arsenic, and hexavalent chromium significantly increases both cancer and non-cancer health risks, with incremental lifetime cancer risk values far exceeding acceptable limits and persistent impairment of lung function, even after adjustment for confounding factors. Cross-sectional risk assessments further show that exposure to respirable silica is strongly associated with reduced lung function parameters (FVC and FEV_1) and elevated airway inflammation biomarkers, while manufacturing workers exhibit substantially higher lifetime cancer risk compared to administrative workers. Collectively, these findings indicate that prolonged exposure to respirable silica not only compromises respiratory function but also markedly elevates lifetime cancer risk, underscoring the necessity of strict exposure control even at regulated workplace levels[19].

Risk assessment based on real-time measurements demonstrated that RQ values ranged from 0.13 to 1.06 mg/m^3/year. Notably, 13.3% of workers exhibited RQ values greater than 1, indicating an unsafe level of exposure to respirable dust and an increased risk of developing occupational health problems. To minimize the adverse effects of dust exposure in the work environment, several control measures are recommended, including engineering controls to reduce dust at the source, consistent use of personal protective equipment (PPE), and periodic pulmonary function examinations. Understanding these exposure-related risk factors is essential for improving workplace safety performance and enabling organizations to design more effective and sustainable occupational health and safety strategies [20, 21,22].

In the present study, there was no statistically significant difference in IL-8 levels based on respirable dust exposure among the marble workers. This finding aligns with research in the ceramic industry, which similarly reported that dust exposure did not significantly correlate with IL-8 as an inflammatory biomarker[23]. Sirait et al., further emphasized that IL-8 levels are not solely determined by workplace dust concentrations, and recommended that additional inflammatory biomarkers, such as C-reactive protein (CRP), tumor necrosis factor-alpha (TNF-α), and interleukin-6 (IL-6), be assessed to provide a more comprehensive evaluation[23]. These results contrast with findings from Hutabarat et al., who reported a positive correlation between wood dust exposure and serum IL-8 levels in workers[5]. The discrepancies may be explained by the fact that respirable dust levels in the present study were all below the threshold limit value (TLV), limiting the ability to detect a significant association between dust exposure and IL-8. Furthermore, the relatively small sample size may have contributed to reduced statistical power, potentially obscuring the effect of respirable dust on IL-8 levels.

Meanwhile, according to the NIOSH Recommended Exposure Limit (NIOSH REL) and Indonesian Minister of Manpower Regulation No. 5 of 2018, the threshold limit value for crystalline silica is set at 0.025 mg/m^3[16,24]. Based on the silica dust measurements, concentrations in the polishing, sawing, and finishing units were found to exceed the threshold limit value (TLV). The highest exposure was observed in the finishing unit, where workers encountered silica dust levels of 0.1114 mg/m^3. This study demonstrated a significant difference in IL-8 levels based on workplace silica dust concentrations, indicating a tendency for IL-8 levels to increase with higher silica dust exposure. This consistent with findings by Herseth, who reported that crystalline silica can induce elevated IL-8 concentrations[25]. Silica-laden dust disperses into the workplace air and is subsequently inhaled by workers. Once inhaled, silica dust can remain in the lungs for an incubation period of approximately 2 to 4 years, which may be shortened if the airborne concentration is high and inhaled in large quantities, accelerating the onset of silicosis symptoms[26]. Long-term occupational exposure to silica is known to cause irreversible pulmonary damage, often leading to pulmonary fibrosis and even lung cancer. Pneumonia represents an initial pulmonary response to silica exposure, involving the release of cytokines, cell death, cell proliferation, and remodeling of alveolar structures[25].

Daily exposure to occupational hazards places marble artisans at high risk for respiratory and systemic diseases. Airborne particulate matter in each work unit is a major contributor to these occupational health risks. Continuous inhalation of silica-containing dust, known for its cytotoxic and pro-inflammatory effects, can lead to severe health outcomes, including pulmonary fibrosis and obstructive lung disorders. Based on the results of silica dust measurements in all work units, also exceeded the TLV, this condition highlights the need for effective dust control and regular monitoring. Continuous exposure to silica dust in the workplace is associated with increased interleukin-8 (IL-8) levels, and periodic monitoring of this cytokine can serve as a biomarker for detecting inflammation and pulmonary dysfunction in marble artisans.

Age and Work Duration Factors

In this study, no significant correlation was found between age and IL-8 levels in the blood serum of marble workers. Consistent with these findings, Flori (2019) reported no correlation between IL-8 concentrations and age in children in studies on Acute Respiratory Distress Syndrome or Pediatric Acute Respiratory Distress Syndrome

(ARDS/PARDS)[27]. The lack of an effect of age on IL-8 levels is attributed to children being in a critical condition with a significant inflammatory response and high variability. This study's findings also support results from research on healthy individuals aged 20–90 years, which showed that IL-8 levels did not differ significantly across age groups. IL-8 is considered one of the most important chemokines and is likely not influenced by age[28]. The somewhat different results are also explained by Qian et al. (2014), who reported that older adults exhibited lower IL-8 levels due to stimulation via Toll-Like Receptor 1 (TLR1)[29]. This study also does not align with Tobis et al. (2006), who reported a positive correlation between subjects' age and IL-8 levels ($r = 0.450$; $p < 0.0001$), indicating that increasing age was associated with higher IL-8 levels in the blood serum. However, in centenarian subjects, IL-8 may serve two different roles: as a marker of chronic inflammation or as a protective mechanism[30].

The findings of this study also showed no statistically significant difference in IL-8 levels based on work duration groups (<10 years vs. ≥10 years; $p = 0.758$). Another study by Dai et al. (2016) reported a tendency for IL-8 levels to decrease with longer exposure to Diesel Engine Exhaust (DEE), although the trend was not statistically significant ($p = 0.078$)[31]. The reduction in cytokine levels induced by long-term DEE exposure is likely related to pathological immune injury. In studies on oil refinery workers, changes in IL-10 levels were found to be significantly associated with work duration, with longer employment correlating with more pronounced changes[32]. Research on the correlation between IL-8 and work duration remains limited and shows varied results. However, there is both a biological and empirical basis suggesting that long-term exposure to irritants in the workplace can lead to inflammation and impaired lung function. Given that IL-8 is a key biomarker of airway inflammation that also increases under such conditions, the indirect association between work duration and IL-8 levels remains relevant. One supporting study by Perez et al. (2021) demonstrated a correlation between duration of exposure and the occurrence of silicosis in workers, most of whom had a history of working in granite mines ($p = 0.031$), indicating the potential of IL-8 as a biomarker for silicosis[33].

Personal Protective Equipment (PPE) Usage Factor

Questionnaire analysis revealed that some workers in the finishing unit (highest dust exposure) did not consistently use personal protective equipment (PPE), resulting in direct inhalation of dust. In this study, PPE primarily consisted of cloth and medical masks, none of which were equipped with cartridges or filters capable of effectively preventing micron-sized particles from entering the respiratory tract. Inconsistent PPE use emerged as a critical concern, contributing to frequent respiratory complaints, including coughing, phlegm production, wheezing, shortness of breath, chest pain, and atopy. These symptoms are consistent with obstructive respiratory disorders often associated with workplace particle exposure.

This study also demonstrated a significant difference in IL-8 levels based on the frequency of personal protective equipment (PPE) use. Properly fitted face masks are known to remove 48–75% of ambient airborne particles with diameters ranging from 5.6 to 560 nm, thereby preventing inhalation of dust that can cause airway irritation[34]. Zainuri and Rachmalia (2016) similarly reported that consistent mask usage reduces inhaled dust exposure, indicating a potential indirect relationship between mask-wearing habits and IL-8 levels, as irritant exposure that affects the respiratory system is reduced and lung function is better preserved[35, 36]. Therefore, daily and proper use of PPE can prevent respiratory problems, including pulmonary function impairment, and limit increases in IL-8 concentrations. Occupational health and safety management needs to ensure the availability of standard-compliant masks and improve worker compliance through training and monitoring.

Inconsistent PPE use may also be explained by low perceived behavioral control, where workers perceive limited ability or support to consistently engage in safe behaviors despite having positive safety intentions. According to the Theory of Planned Behavior, stronger control beliefs enhance an individual's perception of ease in performing protective behaviors, thereby increasing compliance with PPE usage and reducing occupational exposure risks[37].

Pulmonary Dysfunction Factor (Shortness of Breath Complaints)

Based on spirometry results, most marble artisans had normal lung function, while a small portion were identified with pulmonary function impairment ranging from mild to moderate restrictive and obstructive-restrictive patterns. In this study, differences in IL-8 levels were observed between workers who reported shortness of breath and those who did not, suggesting a correlation between IL-8 levels and early symptoms of pulmonary dysfunction. IL-8 levels tended to be higher in workers with shortness of breath complaints compared to those without. Elevated IL-8 leads to excessive neutrophil accumulation in the lungs, allowing proteolytic enzymes and free radicals to damage lung tissue. Additionally, increased IL-8 levels and neutrophil accumulation, combined with silica dust exposure, are known to reduce lung elasticity and contribute to shortness of breath complaints[20].

Supporting evidence from research conducted at the Occupational Health and Allergy Section of the Clinical Hospital in Minsk demonstrated that patients with silicosis at early disease stages (groups 1 and 2, based on X-ray evaluation) exhibited higher IL-8 levels compared to healthy controls and those with severe silicosis (group 3), indicating that IL-8 may increase at the onset of pulmonary fibrosis[31]. Elevated IL-8 has been associated with both the presence and progression of silicosis, highlighting its potential role as a biomarker for early detection[28]. Studies on asthma patients have shown that higher sputum IL-8 levels are associated with accelerated decline in FEV1 lung function, suggesting that this cytokine can serve as a biomarker for long-term pulmonary function decline[32]. However, some studies, such as those conducted on stone-grinding workers in Iran, did not find a significant association between IL-8 levels and silicosis risk, likely due to the multifactorial nature of the disease and the influence of other dominant variables[33]. Furthermore, other research indicates that workers' lung function can also be negatively impacted by dusty environmental conditions, smoking habits, inadequate use of protective masks, prolonged exposure, and pre-existing respiratory conditions[34-36].

This study demonstrated a significant difference in IL-8 levels based on PPE usage, silica dust concentration, and complaints of shortness of breath complaints among marble workers. In contrast, no significant correlation was found between age and IL-8 levels, and there was no significant difference in IL-8 levels based on work duration or respirable dust concentration. The statistically non-significant correlations and differences may be attributed to the relatively small sample size. Therefore, further studies with larger sample populations are highly recommended for more robust results.

The study design used was cross-sectional, which does not allow for analysis of causal relationships or temporal changes in IL-8 levels. Additionally, self-reported data on shortness of breath complaints and PPE usage may introduce bias. The statistical analysis used in this study was non-parametric tests because IL-8 data were not normally distributed; while appropriate for the data characteristics, these tests have limitations in evaluating interactions between variables and simultaneous effects. Therefore, future studies are expected to use parametric tests and multivariate analyses to more accurately explain the relationship between IL-8 and pulmonary dysfunction.

Consistent with the previous discussion, controlling potential biases and confounding variables is necessary to elucidate differences in IL-8 levels based on shortness of breath complaints. In this study, several factors that could potentially act as confounders were not analyzed, such as smoking habits, body mass index (BMI), nutritional status, and work-related fatigue. The majority of respondents were smokers, and several studies have reported a significant association between tobacco exposure and increased IL-8 levels[18,37]. According to Kim et al. (2006), IL-8 levels were positively correlated with BMI ($p < 0.01$) and waist circumference ($p < 0.03$)[38]. Malnutrition risk was negatively correlated with inflammation measured by IL-8 concentration ($p = 0.04$) [39]. Other studies have shown that post-stroke patients experiencing fatigue had higher IL-8 levels compared to those without fatigue[40].

Based on these limitations, further research is warranted to investigate the interplay between smoking habits, BMI, nutritional status, and work-related fatigue with IL-8 levels, which to date have not been comprehensively understood. Follow-up studies are needed that more accurately evaluate the correlation between IL-8 levels and pulmonary dysfunction by minimizing potential biases and controlling for confounding variables. The implications of this study suggest that IL-8 levels have the potential to serve as a strategic biomarker in monitoring lung function and worker health, enabling the detection of inflammation before more severe lung damage occurs. These findings can also provide a basis for the implementation of comprehensive occupational health and safety programs, including the provision of standard-compliant PPE (especially dust-filtering masks), as well as training and monitoring of PPE compliance. Periodic biomarker monitoring can protect workers from the risks of long-term respiratory disorders while simultaneously improving their overall quality of life.

CONCLUSION

This study confirms that IL-8 levels significantly increase in marble workers with higher silica dust exposure, those who never use PPE, and those experiencing shortness of breath symptoms. Conversely, no differences in IL-8 levels were observed based on respirable dust exposure or work duration groups in the workers' blood serum. Additionally, IL-8 levels were found not to correlate with workers' age. These findings highlight the critical role of risk management in preventing pulmonary function impairments caused by occupational dust exposure. Enhancing awareness and compliance with consistent PPE usage, as well as implementing routine monitoring of IL-8 as a biomarker for early detection of pulmonary dysfunction, should be prioritized in occupational health programs. Furthermore, future research with larger sample sizes should aim to explore the long-term impact of IL-8 as a biomarker of inflammation and pulmonary function impairment.

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