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Occupational Exposure to Dust and the Relationship with the Respiratory Symptoms, Lung Function among Construction Workers of the University of Malaysia Sabah

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Abstract

BACKGROUND: The respiratory tract often becomes the site of injury from occupational exposure. All construction sites generate high levels of dust, typically from concrete, silica, asbestos, cement, wood, and stone, sand, and therefore, the workers are exposed to this airborne dust and increased their risk of developing respiratory disorders. Limited studies have been conducted to assess the relationship between respiratory symptoms, lung function, and occupational dust exposure among construction workers in Sabah.

AIM: The objectives of this study are to determine the occupational exposure to dust and the relationship with the respiratory symptoms as well as lung function among construction workers in UMS Teaching Hospital.

MATERIALS AND METHODS: This cross-sectional study consisted of construction workers working in all sections in the development of UMS Teaching Hospital. A standard respiratory questionnaire was distributed to construction workers and lung function measurement was performed using Spirometry and the results of their respiratory status were compared between workers who were exposed and unexposed to dust. Occupational dust exposure was determined by the gravimetric method using an air sampler. The total duration of the collection was 8 h and the filters with the dust samples were analyzed in the laboratory.

RESULTS: The result showed three parameters that were significantly associated with respiratory symptoms, namely, age, marital status, and smoking status. Male workers had a higher prevalence (42.7%) of having respiratory symptoms compared to female workers (21.4%). Widow/widower/divorced (50.0%) had a higher prevalence of having respiratory symptoms compared to married (45.8%) or single workers (25.0%). Workers who smoke had a higher prevalence (51.2%) of having respiratory symptoms compared to non-smoker's workers (22.7%).

CONCLUSION: The highest dust exposure is the piping workstation, followed by the cement and plastering workstations. These warrant the compulsory use of personal protective equipment by construction workers during work, improving the quality of dust masks, and standardizing their usage. Effective engineering controls should also be promoted on construction sites.

Introduction

The construction industry is often criticized for being one of the heavy polluters that generate dust in the atmosphere from construction works [1]. Construction activities generate a large amount of dust. Chen *et al*. (2019) stated that even with more advanced construction technology and perfect construction administration, workers in the construction industry are still suffering from dust pollution containing massive hazardous materials, such as silica [2]. All construction sites generate high levels of dust, typically from concrete, silica, asbestos, cement, wood, stone, and sand, where the workers are exposed to this airborne dust [3], [4]. Dust originating from work operations like drilling, blasting, and grinding becomes airborne, where inhalation of the particles may induce accelerated lung function decline [5]. Bandyopadhyay and De (2015) also stated that airborne silica dust is generated during chasing or drilling into concrete, brickwork, ripping up old concrete, and excavating sites with sandstone or clay. Workers are exposed to this airborne dust in construction sites [6]. Building construction dust refers to the diffusion of particulate matter in the atmosphere caused by construction sites and activities [7], [8]. Most masonry building materials contain quartz and as these materials are subjected to a variety of treatments during the building process, quartz is encountered everywhere during building operations. Lumens and Spee (2001) did a study on the level of exposure to respirable quartz and measured some highly exposed groups of employees at 30 construction sites [9]. Personal air sampling (PAS) measurements of respirable dust and quartz were performed and 171 samples were taken. Both respirable dust and quartz levels were high. Respirable quartz exposures were more than ten times the Dutch limit value of 0.075 mg/m^3 TWA.

The occupational-related lung diseases are most likely due to the deposition of dust in the lung and are influenced by the sort of dust, the period of exposure, the concentration, and the size of the airborne dust in the breathing zone [6], [10]. One of the main problems encountered in the working environment of construction sites is respirable dust. Exposure to ambient particulate air pollution is associated with an increase in morbidity and mortality, in the form of respiratory and cardiovascular diseases [11]. Construction dust is classified as PM-10, that is, particulate matters of <10 μm diameter and workers are at risk of inhaling these particles [6]. Normohammadi *et al*. (2016) also stated that respirable crystalline silica is a very small particle of at least 100 times smaller than ordinary sand, where it is produced by construction activities, such as crushing concrete blocks [12]. The respiratory tract is often the site of injury from occupational exposure. The widespread use of potentially toxic materials in the environment poses a major threat to both airways and lung parenchyma. It can cause significant negative impacts on human health and influence the air quality of the surrounding area within the construction site. Workers in construction industries are exposed to occupational hazards, such as health hazards and occupational injuries [12]. Individuals working in dusty environments are at risk of inhaling particulate materials that may lead to adverse respiratory effects [13]. A large exposure survey was carried out by Bakke *et al*. (2004) to estimate personal exposure levels to several chemical agents and found that construction workers were at increased risk of obstructive pulmonary disease, where a cumulative exposure to respirable dust and a-quartz appeared to be the most important risk factors [14].

Dust and cement particles that are inhaled will be lodged in the lungs and causes lung irritation, mucus hypersecretion, followed by impairment of pulmonary function, inflammation, chronic obstructive pulmonary diseases, restrictive lung diseases, pneumoconiosis, and so on [15], [16], [17], [18]. Exposure to silica dust can be considered the most important hazard in construction activities as it is the fundamental building block of structures. It can become a potent lung toxin and have a risk of developing serious silica-related diseases, such as silicosis, lung cancer, chronic obstructive pulmonary disease, and kidney disease [12]. A particularly important disease among these is silicosis, which is lung fibrosis that may advance to progressive massive fibrosis, at which stage, the individual suffers severe respiratory distress. Acute silicosis, due to high exposure to silica over a short period, causes rapidly progressive breathing difficulty and may be fatal within months of onset. In addition, silicosis can predispose the sufferers to other ailments, such as tuberculosis; and silica inhalation is associated with carcinogenic activity [19]. American Thoracic Society conducted a systematic epidemiologic review and concluded that approximately 15% of Chronic Obstructive Pulmonary Diseases cases may be attributable to workplace exposures [20].

A cross-sectional study on radiographic abnormalities indicative of pneumoconiosis was conducted by Tjoe Nij *et al*. among 1339 construction workers, mainly involved in grinding, jack-hammering, drilling, cutting, sewing, and polishing [3]. The study suggests an elevated risk of radiographic abnormalities among these workers with expected high exposure. An association between radiographic abnormalities and cumulative exposure to quartz-containing dust from construction sites was observed, after correction for potentially confounding variables.

The risk of death due to silicosis after 45 years of silica dust exposure (0.05 mg/m^3) in a pooled analysis of six cohorts was six in 1000 and the Occupational Safety and Health Administrative (OSHA) has determined that the acceptable level of risk is one in 1000 workers [21]. Rappaport *et al*. (2003) reported that numerous construction workers have been overexposed to crystalline silica dust in construction sites and the highest exposure was found in painters (1.28 mg/m^3) compared to laborers, bricklayers, and operating engineers [22]. Bergdahl *et al*. did a study on a cohort of 317,629 Swedish male construction workers from 1971 to 1999 [23]. Exposure to inorganic dust (asbestos, man-made mineral fibers, dust from cement, concrete, and quartz), gases and irritants (epoxy resins, isocyanates, and organic solvents), fumes (asphalt fumes, diesel exhaust, and metal fumes), and wood dust were based on a job-exposure matrix. The analyses were adjusted for age and smoking. When all subjects were analyzed, there was increased mortality from COPD among those with any airborne exposure (relative risk of 1.12 with 95% confidence interval (CI) of 1.03–1.22). Chisholm (1999) also stated that over the past few years, there has been a growing recognition of the risk of respiratory disease related to the exposure to dust containing crystalline silica released during various activities in the construction industry [24]. Of all silicosis deaths in the US (1968–1990), for which industry and occupation data are available, the highest proportion was accounted for by the construction industry, making up for more than 10% of the total. Flanagan *et al*. (2003) also stated that Silica exposure has been associated with excess disease for construction populations [25]. More silicosis deaths were associated with construction than any other industry, and significantly elevated mortality risk from silicosis has been observed among construction workers.

All construction sites generate high levels of dust, typically from concrete, silica, asbestos, cement, wood, stone, and sand, and therefore, the workers are exposed to this airborne dust and increase their risk of developing respiratory disorders. The disability due to respiratory disorders will result in sickness absence, loss of work, production loss, and costs to the employers and welfare system.

Even though studies of occupational lung disease at the construction sites had been done in other places of the world, but the material and the methodology of work may differ in Sabah, Malaysia. There were limited studies been conducted to assess the relationship between respiratory symptoms, lung function, and occupational dust exposure among construction workers in Sabah. Furthermore, there were no available data of numbers of pneumoconiosis and the general occupational lung disease in Sabah. Thus, the researcher would like to do you know the level dust exposure, the prevalence of occupational lung disease, and the relation between these two. Hence, this study aims to determine the occupational exposure to dust and the relationship with respiratory symptoms as well as lung function among construction workers at UMS Teaching Hospital.

Methods

Study design and setting

This cross-sectional study includes construction workers working in all work units in the development of UMS Teaching Hospital. The work units are metal, piping, cement, bricklaying, plastering, and carpentry work units.

Sample size calculation

The formula for sample size calculation is based on a comparison of two proportions by Kirkwood and Robert (2010) [26]. Thus, the calculated sample size is 100. Following the consideration of a 95% confidence interval, 80% statistical power with 10% non-response rate, the final sample required for this study is 110.

Data collection

Assessment of the respiratory symptoms

The Standardized respiratory health questionnaire was used, based on the American Thoracic Society Respiratory Symptom Questionnaire, which was adjusted to fit the working conditions at the construction site [27], [28]. The questionnaire consisted of four parts, including general information, working history and environment, smoking and drinking history, and the history of respiratory disorders, which is divided into two groups of respiratory symptoms: irritation and allergic symptoms. Answers were marked 0 for no respiratory symptoms and one for having respiratory symptoms.

Lung function test

The lung function tests or pulmonary capacity of the subjects were determined using a portable MIR Spirobank II Spirometer made by Medical International Research (MIR) Company, based in Rome, Italy. Spirometry was performed on a computerized MIR Spirobank II Spirometer. This software allows the calculation of the predicted values for age, sex, weight, and height and it also gives the recorded values of all the parameters. The tests were conducted by a technician in a sitting position for all subjects. The tests were performed and repeated three times after adequate rest and the results obtained were collected in the form of a printout from the Spirometer. The parameters taken into account were forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), forced expiratory ratio (FEV1/FVC%), peak expiratory flow rate (PEFR), and forced expiratory flow (FEF25-75%). The results were presented as mean ± SD and percentage difference. The unexposed workers were examined with the Spirometry. The lung function statuses of the exposed workers were compared with the unexposed and the deviation in their status was assessed, both numerically and statistically. The result evaluation refers to the standard published by American Thoracic Society. Moreover, the final criteria for this measurement result will be based on prediction according to standardized age, gender, ethnicity, and height.

Data collection for dust exposure

A personal air sampler was used to collect the dust. The brand of the air sampler is GilAir Plus manufactured by Sensidyne Gilian Company based in United States of America. The total duration of the collection was 8 h, and the container with the air samples was analyzed in the laboratory. The result will be compared to the standard in Schedule 2, USECHH Regulation by Department of Occupational Safety and Health, Malaysia.

Statistical analysis

Data analysis was conducted using the statistical software package SPSS (version 22), and the results were presented in tables, frequencies, percentages, means, standard deviations (SD), medians, minimum, and maximum values to explain general variables in the data. Bivariate logistic analysis, namely, Chi-square was used to analyze the association between each independent variable and respiratory symptoms and the lung functions individually.

Results

Descriptive analysis

The sociodemographic characteristics of the respondents are shown in Table 1. The descriptive analysis showed that among the 152 participants, majority 124 (81.6%) were male and 28 (18.4%) were female. They had worked ranging from 1 week to 8 years. Most of the workers are at the age of 15–24 years old (32.2%) and from Suluk ethnicity (79.6%) which non-Malaysia citizen (84.9%). Majority of the workers also had no education (51.3%).

Table 1: Sociodemographic characteristics of the respondents (n = 152)

Characteristics	Frequency, n	Percentage
Age group in years		
<14	2	1.3
15–24	49	32.2
25–34	34	22.4
35–44	30	19.7
45–54	23	15.1
55–64	12	7.9
>65	2	1.3
Gender		
Male	124	81.6
Female	28	18.4
Ethnicity		
Suluk	121	79.6
Bajau	14	9.2
Kadazan-Dusun	8	5.3
Malay	4	2.6
Others	5	3.3
Citizenship		
Citizen	23	15.1
Non-citizen	129	84.9
Status		
Married	96	63.2
Single	52	34.2
Divorced	4	2.6
Education level		
No education	78	51.3
Primary	39	25.7
Secondary	22	14.5
Tertiary	13	8.6
Working in the position		
Yes	116	23.7
No	36	76.3
Working in dusty area previously		
Yes	91	59.9
No	61	40.1
Cough 4 days a week		
Yes	24	15.8
No	23	15.1
Unsure	105	69.1
Cough 3 months or more a year		
Yes	4	2.6
No	43	28.3
Unsure	105	69.1
Cough 2 years consecutively		
Yes	1	0.7
No	46	30.3
Unsure	105	69.1
Phlegm more than 2 weeks		
Yes	15	9.9
No	20	13.2
Unsure	117	77.0
Phlegm more than 3 months		
Yes	0	0
No	34	22.4
Unsure	118	77.6

Bivariate analysis

Based on Table 2, we conclude that there is a significant association between gender and respiratory symptoms. Male workers have a higher prevalence of respiratory diseases than female workers.

Table 2: Association sociodemographic with respiratory symptom

Characteristic	Respiratory symptom		Chi-square	p-value*
	Symptomatic (%)	Asymptomatic (%)		
Gender			4.369	0.037
Male	42.7	57.3		
Female	21.4	78.6		
Status			6.381	0.041
Single	25.0	75.0		
Married	45.8	54.2		
Widow/widower/ divorced	50.0	50.0		
Smoking			12.714	<0.05
Yes	51.2	48.8		
No	22.7	77.3		

*Chi-square test (χ^2).

Therefore, 42.7% of male workers have respiratory symptoms, while only 21.4% of female workers have respiratory symptoms. We also concluded that there is a significant association between marital status and respiratory symptoms. Compared to married or single workers, widows/widower/divorced persons have a higher prevalence of respiratory symptoms. Therefore, 50.0% of widows/widower/divorces have respiratory symptoms, while married and single laborer only 45.8% and 25.0% of the patients had respiratory symptoms. In addition, we concluded that there is a significant association between smoking and respiratory symptoms. Compared with non-smokers, smokers have a higher prevalence of respiratory diseases. Therefore, 51.2% of smokers have respiratory symptoms, while only 22.7% of non-smokers have respiratory symptoms.

Risk estimate of smoking and respiratory symptoms

Table 3 shows the odds ratio of smokers compared to non-smokers having respiratory symptoms, which were 2.251 (95% CI: 1.379–3.676) and means that the smokers had 2.2 times higher of having respiratory symptoms compared to non-smokers.

Table 3: Risk estimate of smoking and respiratory symptoms

Risk estimate	Value[a]	95% Confidence Interval	
		Lower	Upper
Odds ratio for SMOKING (Yes/No)	3.562	1.744	7.276
For cohort respiratory symptoms = Yes	2.251	1.379	3.676
For cohort respiratory symptoms = No	0.632	0.491	0.814

[a]Logistic regression.

Independent sample t-test of age and respiratory symptoms

To compare means, T-value is 3.356 significant at 5% with p-value of 0.001 based on Table 4. Hence, we conclude that there is a significant association between respiratory symptoms and age.

Table 4: Independent sample t-test of age and respiratory symptoms

Characteristic	Respiratory symptoms	N	Mean	SD	T	p-value
Age	Yes	59	38.02	15.072	3.356	0.001*
	No	93	30.49	12.349		

*t-test.

Dust sampling

A total of 12 samples were taken from A random sampling of two samples was taken from each work unit.

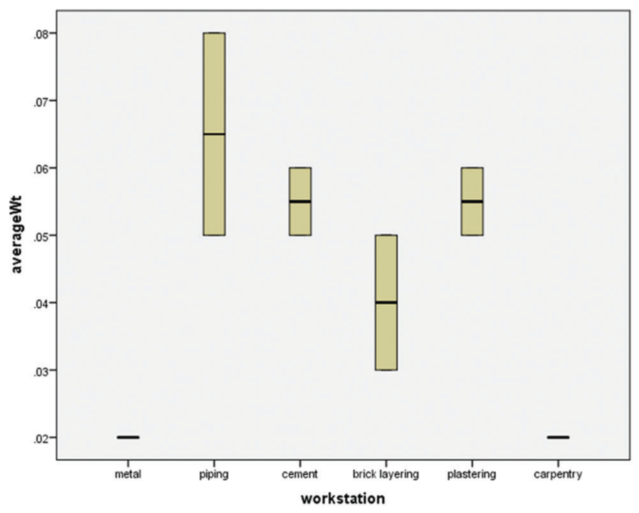

Figure 1: Dust exposure by workstation

The filter cotton was weighed before the worker's air sampler was installed. The mean weight of the filter cotton before sampling was 0.1017 and the mean weight of filter cotton after sampling was 0.1442. There was a 0.0425 increment in personal air sampling. In 8 h projection, the mean of dust exposure to the workers was 0.34 g. The highest dust exposure was the piping workstation, comprising 0.52 g of dust with an 8-h projection, followed by cement and plastering (Figure 1). Most of them have no proper personal protective equipment (PPE). Some that have PPE also did not wear them properly and only use a cotton cloth to cover their face (Table 5).

Table 5: Dust exposure per workstation

Workstation	Average of dust exposure per work unit (g)	Dust exposure in 8 h (g)	PPE
Metal	0.02	0.16	No
Piping	0.065	0.52	No
Cement	0.05	0.40	Cloth
Bricklaying	0.04	0.32	Cloth
Plastering	0.05	0.40	Cloth
Carpentry	0.02	0.16	Cloth

Discussion

Three (3) parameters were significantly associated with respiratory symptoms, namely, age, marital status, and smoking status. The study also found that there is a significant association between gender and respiratory. Male workers had a higher prevalence of having respiratory symptoms compared to female workers. These findings were consistent with a study done by Dement *et al*. (2010), which stated that the workers with COPD were significantly older, more likely to be males, and worked significantly longer at DOE sites and in the construction trades [29]. These findings were also consistent with a study by Da-Silva-Filho *et al*. (2019) that found the prevalence, prevalence ratio, and confidence interval for variables associated with cough, phlegm, wheezing, and respiratory symptoms were higher in male workers compared to female workers [30]. Thus, control measures such as training, health education, and use of PPE should be targeted to the male workers.

This study also found a significant association between marital status and respiratory symptoms (Pearson Chi-Square value was 6.381 with p-value of 0.041, which is significant at a 5% significance level). Widow/widower/divorced had a higher prevalence (50.0%) of having respiratory symptoms compared to married (45.8%) or single workers (25.0%). However, the author had not found other studies with similar significant findings. A study by Ghasemkhani *et al*. (2006) showed no significant association between marital status and respiratory symptoms [31]. Thus, health check-up should be more targeted and through among widow/widower/divorced workers as this group had higher prevalence of having respiratory symptoms.

There is a significant association between smoking and respiratory symptoms (Pearson Chi-Square value was 12.714 with $p < 0.05$, which is significant at a 5% significance level). Workers who smoke had a higher prevalence (51.2%) of having respiratory symptoms compared to non-smokers workers (22.7%). These findings were consistent with many studies, such as by Ulvestad *et al*. (2000) that found respiratory symptoms were significantly associated with smoking among construction workers [5]. The results of the study by Bandyopadhyay and De (2015) showed increase symptoms and a significant decrease in the mean values, as well as the percent predicted value of FVC, FEV1, %FEV1/FVC, PEFR, and FEF25 – 75% in construction workers [6]. A study by Arcangeli *et al*. (2004) also concluded that the prevalence of cough and expectoration was higher in workers and smokers, showing that environmental work exposure and smoking habits can influence those kinds of symptoms [31]. The increase in chronic obstructive pulmonary disease is well documented in smokers and those suspected of heavy construction work. Thus, the prevalence of workers who smoked should be reduced by introducing campaign as quite smoking to reduce the incidence of respiratory symptoms.

The mean of dust exposure to the workers was found to be 0.34 g. The highest dust exposure is the piping workstation, consisting of 0.52 g of dust with an 8-h projection, followed by cement and plastering. This finding was consistent with a case study carried out by Peters *et al*. (2009) in 2006–2007 to assess the actual cement dust exposure among construction workers [32]. He found that the highest inhalable (cement) dust concentrations at the construction site were observed for concrete repairers, floor screed layers, and tile setters. Thus, control to reduce dust concentration in piping workstation should be enhanced. Control such as engineering control should be introduced for example using vacuum and wet method. If a wet system is used, attention must be directed at the flow rate since dust control is ineffective when the flow rate is inadequate [19]. It is important, however, that the pressure in the supply reservoirs is properly maintained, that the water is correctly applied and that it is used at the correct rate. Effective dust control can be achieved if this is done. Other effective methods are using PPE such as dust masks. As Chen *et al*. (2019) stated, wearing dust masks in construction sites can reduce the health risk by up to 82% (ideal isolation effect) and the worst is 26% (actual isolation effect) [2]. However, exposures are often high, and respirators are not always protective enough. The use of controls was infrequent and usually did not control exposures below the TLV [25], [33]. Effective engineering controls should be promoted on construction sites.

This research has certain advantages and limitations. Since the design of the study is cross-sectional, the goal of the study can be achieved in a short time and at a relatively low cost. Self-reported symptoms may lead to an underestimation of symptoms among workers. Some workers may worry about losing their jobs if they admit that they have health problems. In this study, this may be reduced due to the privacy settings of the interviews and the privacy guarantees of the information they provided. In addition, the study design only enabled the measurement of prevalence but was not able to prove any causal relationship.

Conclusion

Construction workers in Malaysia are at increased risk of developing occupationally related pulmonary impairment. We recommend the compulsory use of personal protective equipment by construction workers during work. Improving the quality of dust masks and standardizing their usage would greatly improve the health level. Research to assess the effectiveness of available controls is needed to assist the industry in identifying effective controls and reducing exposures. Both LEV and the proper application of water can reduce levels significantly and for this reason, the use of control systems should be encouraged.

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Authors Contributions

M S.S., F.H., K.A.L., S.S.S.A.R., M.S.J, H.L., and F.K. contributed to the original idea, designed and coordinated the study, and revised the final draft critically for important intellectual content. S.S., F.H., K.A.L., S.S.S.A.R., and A.R.R. conceptualized the study and involved in data collection. A.R.R., S.S., F.H., and S.S.S.A.R. assisted in statistical analysis, interpreted the results and drafted the manuscript.

Ethical Approval Statement

The study was approved by the Universiti Malaysia Sabah Medical Research Ethic Committee with the approval number of JKEtika 3/18 (9).

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