ORIGINAL ARTICLE

RESPIRATORY SYMPTOMS AND PULMONARY FUNCTION AMONG MALE STEEL WORKERS IN TERENGGANU, MALAYSIA

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ABSTRACT

A cross sectional study was carried out to determine the relationship between dust exposure and pulmonary function in male steel workers in Terengganu, Malaysia. The investigation included spirometric testing and detailed personal interviews using a structured questionnaire adopted from British Medical Research Council (BRMC) Questionnaire on respiratory symptoms. Respiratory symptoms commonly reported by the male workers were morning phlegm (33.1%), shortness of breath (31.9%), chest tightness (30.4%), and morning cough (17.8%). Age and duration of employment were among the factors associated with respiratory symptoms ($p<0.05$ and $p<0.001$ respectively). Forced Expiratory Volume in 1 second (FEV_1) was significantly reduced when compared to the healthy population. There was a significant decrease of FEV_1 between before and after work shift ($t= 3.582$, $p<0.001$). Smoking status, age, and duration of employment were also associated with reduction of pulmonary function ($p<0.01$).

Keywords: respiratory symptoms, pulmonary function, steel workers, metal dust, occupational respiratory diseases

INTRODUCTION

Malaysia is a developing country and experiencing rapid growth in industrialization. There is a significant proportion of the population working in the manufacturing sector. Steel manufacturing also contributes to the nation's economy. Steel making processes produce fumes, dust, and pollutant gases. Steel workers are potentially exposed to a variety of pollutants originating from iron ore, coal, and silica that may adversely effects their respiratory health. Several studies reported that unprotected dust exposures in steel making production may lead to lung function impairment [1, 2, 3].

Dust has a long history of association with diseases and known to give adverse health effects on various organs such as eye, nose, skin and the airways have been described [4,5]. Chronic obstructive airway diseases have been well documented as being result of such exposure. However, few studies have been reported on the effect of metal dust exposure. Metal dust is known to have high metallic content[6]. This metallic dust may cause pulmonary diseases namely pneumoconiosis, bronchitis, and possible lung cancer [7, 8]. They were limited local data published since the preliminary report. Thus we conducted a cross sectional study of respiratory symptoms and pulmonary function in steel workers exposed to metal dusts.

METHODOLOGY

The study population consisted of all workers employed at government owned steel mill in Terengganu. Altogether there were 1000 workers at the time of the study. Sampling frame was all the male workers in production. Universal sampling was used and study samples were recruited based on this following criteria; male, age from 18 to 56 years old and at least one year duration of work. Only 424 workers were recruited randomly, while 96.7% of them completed the questionnaire.

The subjects were interviewed using a standard questionnaire which was based on British Medical Research Council (BMRC) questionnaire. The questionnaire was developed to cover the respiratory symptoms, past medical history, smoking status and occupational history. These symptoms were based on their experience during the last 12 months. The current smokers were defined as those who smoked a tobacco product at the time of the study.

Pulmonary function was measured with a spirometer (Model Spirolab MIR). A total of 402 workers performed spirometric testing according to the requirements of American Thoracic Society (ATS). However, those who are unable to produce acceptable spirograms meeting the ATS (N=22) were excluded from the analysis to enhance the valid contrast. Each subject was asked to inhale deeply in standing position with the nose clamped, blowing rapidly and completely as possible. The procedure was explained and demonstrated to each subject. At least three measurements were taken for each subject. The best flow was recorded and printed. Results were automatically corrected to body temperature. Height and weight were recorded to the nearest 0.5 cm and 0.5 kg respectively.

Data analysis was done using SPSS. Chi Square test was used to identify the association of each respiratory symptom with age, duration of work, and smoking status. One sample t-test was used to compare means of pulmonary function parameter to healthy Malaysian standard. Paired t-test was used to compare mean difference of pulmonary functions in two intervals; before and after shift work. Multiple linear regression analysis was applied to identify the factors associated with pulmonary function values. The outcome variables analyzed were FVC, FEV_1 and $\%FEV_1/FVC$. The significant level used for evaluating the test of significance was set at $p<0.05$.

RESULTS

Four hundred and two workers Malay workers with mean age 36.8 ± 8.81 years were assessed. Forty percent of the workers were more than 40 years old. Mean height and weight were 166.9 cm and 72.4 kg respectively. Mean duration of employment was 12.2 ± 8.23 years of work. Fifty percent of the workers were current smokers. Mean number of cigarettes per day was 11.8 ± 6.78, while the mean years of smoking was 15.1 ± 11.97.

Respiratory symptoms

Symptoms were grouped into four main categories namely morning phlegm, shortness of breath, chest tightness, and morning cough. These symptoms were based on their experience during the last 12 months. Morning phlegm was the most common symptom (33.1%), followed by shortness of breath (31.9%), chest tightness (30.4%), and morning cough (17.8%) (Figure 1). Forty percent of male workers have at least one of the above symptoms, 21.7% at least two symptoms, 11.4% and 1.4% of the workers have at least three and four symptoms respectively.

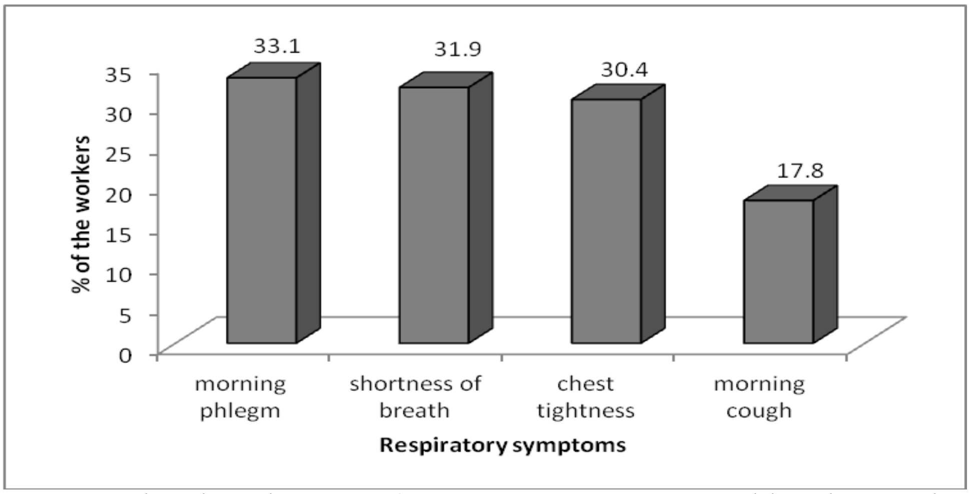

Figure 1: The distribution of symptoms experienced by the workers

Age group had a significant relationship with all the respiratory symptoms. Age was found significantly related to shortness of breath (OR=2.05, 95% CI: 1.40 – 2.99), chest tightness (OR=1.52, 95% CI: 1.03 – 2.23), morning phlegm (OR=1.61, 95% CI: 1.11 – 2.35), and morning cough (OR=2.36, 95% CI: 1.50 – 3.71). Duration of employment was significantly associated with morning phlegm (OR=1.50, 95% CI: 1.04 – 2.16) and morning cough (OR=1.78, 95% CI: 1.13 – 2.80). Smoking status did not have significant relationship with all the respiratory symptoms. Table 1 shows the association of respiratory symptoms with the characteristic of the workers.

Table 1: Relationship between respiratory symptoms with age, duration of employment and smoking status

Symptoms	Demographic characteristics	Odds Ratio (95% CI)[1]
Shortness of breath	Age group[2]	2.05 (1.40,2.99)**
	Duration of employment[3]	1.39 (0.96, 2.01)
	Smoking[4]	1.18 (0.814, 1.707)
Chest tightness	Age group	1.52 (1.03, 2.23)*
	Duration of employment	1.65 (1.14, 2.41)
	Smoking	0.80 (0.55,1.17)
Morning phlegm	Age group	1.61 (1.11, 2.35)*
	Duration of employment	1.50 (1.04, 2.16)*
	Smoking	1.21 (0.84,1.74)
Morning cough	Age group	2.36 (1.50, 3.71)**
	Duration of employment	1.78 (1.13, 2.80)*
	Smoking	0.89 (0.57,1.39)

[1] Age group: 40 years & less (reference group) versus 41 years & above
[2] Duration of employment : 10 years & below (reference group) versus 11 years & above
[3] Smoking status: Current smokers versus non current smokers (reference group)
[4] OR : Prevalence ratio calculations (95% Confident Interval)
* Significance at p or below than 0.05
**Significance at p or below than 0.001

Pulmonary Function

Mean value of forced expiratory volume in one second (FEV_1) and Force Vital Capacity (FVC) was lower when compared to the predicted value of healthy Malaysia population [9]. The difference of FEV_1 was statistically significant from value of observed healthy population (p<0.001), whereas the mean for FVC was not significantly significant (p = 0.158) (Table 2).

Table 2: The pattern of FEV_1 and FVC (N=402)

Parameters	Steel Workers	Malaysia healthy population	Mean difference	t-stat (df)	p value
FEV_1	2.91	3.11	-0.202	-8.72 (401)	p<0.001**
FVC	3.43	3.49	-0.052	-2.00 (401)	p=0.158

**significance at $p \leq 0.001$

A further measurement was done to see the mean difference of pulmonary function into two intervals; between before and after the work shift. The paired t-test showed that FEV_1 between and before work shift was statistically decreased ($t = 3.582$, $p < 0.001$). However, the mean difference of FVC and $\%FEV_1/FVC$ between before and after work shift were not statistically decreased ($p>0.05$).

Table 3: Mean differences of pulmonary function between before and after work shift among workers (N=402**)**

Parameters	**Interval (Mean ± SD)**	**Mean difference (95% CI)**	**t -stat**	**p value**
FVC	Before (3.43 ± 0.238) After (3.42 ± 0.226)	0.004 (-0.004, 0.012)	1.105	0.270
FEV_1	Before (2.91 ± 0.371) After (2.89 ± 0.365)	0.017 (0.008, 0.026)	3.582	p<0.001**
% FEV_1/FVC	Before (83.25 ± 9.69) After (82.94 ± 10.67	0.304 (0.107, 0.715)	1.455	0.146

**Significance at p or below than 0.001

Further analysis revealed that age was significantly related to FEV_1 ($p<0.001$), FVC ($p<0.001$), and $\%FEV_1/FVC$ ($p<0.001$). Duration of employment was also significantly related to FEV_1 ($p<0.001$), FVC ($p<0.001$), and $\%FEV_1/FVC$ ($p<0.001$). However, in age adjusted multiple linear regression models, duration of employment were not related to $\%FEV_1/FVC$. Smoking was not significantly related to FEV_1, FVC, and $\%FEV_1/FVC$ (Table 4).

Table 4: Relationship between each pulmonary function parameters with age, duration of employment, and smoking status

Dependent Variable	Independent Variable	SLR[a]		MLR[b]	
		b[c] (95% CI)	p value	*Adj b*[d] (95%CI)	p value
FEV_1 (R^2 =0.173)	Age (years)	-0.040 (-0.05, -0.03)	<0.001**	-0.041 (-0.058, -0.028)	< 0.001**
	Duration of employment (years)	-0.025 (-0.04, -0.01)	<0.001**	-0.008 (0.002, 0.020)	0.014*
	Smoking (Yes/No)	-0.016 (-0.027, 0.115)	0.228	-0.023 (-0.024,-0.0219)	0.146
FVC (R^2 =0.122)	Age (years)	-0.022 (-0.023, -0.020)	<0.001**	-0.018 (-0.019, -0.017)	<0.001**
	Duration of employment (years)	-0.015 (-0.002, - 0.009)	<0.001**	-0.016 (0.005, 0.026)	0.005*
	Smoking (Yes/No)	-0.037 (-0.008, 0.083)	0.108	-0.005 (-0.223,0.213)	0.066
% FEV_1/FVC (R^2 =0.057)	Age (years)	-0.530 (-0.646, -0.413)	<0.001**	-0.499 (-0.033, -0.030)	<0.001**
	Duration of employment (years)	-0.0222 (-0.414, -0.032)	<0.001**	-0.015 (-0.02, 0.01)	0.298
	Smoking (Yes/No)	-0.798 (-1.071, 1.471)	0.142	-0.009 (-0.284, 0.302)	0.864

[a] Simple linear regression[b] Multiple linear regression
[c] Crude regression coefficients
[d] Adjusted regression coefficients
** Significance at p or below than 0.05
** Significance at p or below than 0.001
The model reasonably fits well. Model assumptions are met. There are no interaction between independent variables and no multicollinearity problem

DISCUSSION

Respiratory Symptoms

This study has found that forty percent of the steel workers complained at least one of the respiratory symptoms. The most common symptom reported was morning phlegm (33.1%) while (17.8%) of the workers had morning cough. This result was comparable with the study by Chen *et al* in Taiwan, who found that 60% of steel workers in Taiwan complained one or more respiratory symptoms; there were cough (20.7%), phlegm (26.5%), and wheezing (33.3%)[10].

The risk of chest tightness, shortness of breath, and morning phlegm were found to be significantly associated with the age group of more than 40 years old (OR: 2.05, 1.52,.1.16, and 2.36 respectively) while duration of works of more than 11 years was found to be significantly associated with morning cough and morning phlegm (OR: 1.50 and 1.78). The risks of shortness of breath and chest tightness were not affected by both duration of employment and smoking status. Coronary artery disease can also be responsible for chest tightness, especially in an all male-study population. The history of cough and phlegm may be due to concomitant of cigarette smoking. Smoking can also explain some of the respiratory symptoms reported but no significant association was found. Perhaps detailed exposure such as numbers of cigarettes and duration of smoking may be associated with the respiratory symptoms reported.

The results supported that steel workers have high prevalence of pulmonary symptoms. The development of respiratory diseases and other work related respiratory symptoms among the steel workers were related to a combination of dusts (which may acts as irritants in their own right) and irritant gases in the workplace as well as the effects of smoking and other ambient air pollution. How these two aetiological factors interact was not known, although it was possible that smoking may alter the handling of agents encountered in the workplace by interfering with the normal mucocillary clearance by more complex mechanisms [11]. In some exposures, the possible interaction between exposure to tobacco smoke and workplace contaminants was greater than each of their individual effects. There was a possibility of occupational asthma, which might be responsible for chest tightness, shortness of breath, and morning cough with phlegm. However, reversible wheezing, an important symptom in asthma was not elicited in this study.

Pulmonary Function

The pulmonary function tests done showed that FEV_1 were comparable to health Malaysian population. Occupational asthma was rather unlikely as FEV_1 will be reduced during acute attacks. Both were found to be reduced, indicating an obstructive and restrictive type of pulmonary condition. A study by Johnson *et al* (1985) found that workers in an iron and steel foundry had significant lower mean of FEV_1, about 5% had a radiological evidence of pneumoconiosis and 18.2% had work related asthma [12]. Gomes (2001) found that the lung function values for FEV_1, FEV_1/FVC were also significantly lower for the exposed group[13]. Kusaka *et al* (1996) reported significant lower of %FVC and %FEV_1 among workers without asthma. However the ventilatory function did not differ between exposed and non exposed workers [14]. It was suggested that the functional impairment in small airways need to be followed up especially among possible asthmatics workers to find the possible association with chronic bronchial obstruction and respiratory failure. Furthermore, longitudinal studies also found significant deterioration of FEV_1 and %FEV_1/FVC among steel workers as compared to a reference group of unexposed workers [15, 16].

There was significant decrease of FEV_1 towards shift ends with a small difference between the intervals. Furthermore, a consistent pattern was found in ventilatory capacity suggesting that a diurnal rhythm in lung function exists. Nemery *et al* (1985) reported the most pronounced decrease in FEV_1 and %FEV_1/FVC was found over the night shift of strand casting workers [17]. These changes were exceedingly small (approximately 100 – 200 mL over an 8-hour shift) and were poorly standardized for the time of waking. In contrast, FVC and %FEV_1/FVC were not statistically decreased even though a small decrement was found towards the shift. It seemed that there was a considerable difference in the pulmonary function during the working shift. In addition, this pattern might be influenced by other factors, such as the time of the day, shift they were working with, and types of work as well as possible lifestyles.

Factors Influencing Pulmonary Function

Age, duration of work, and smoking status influenced FEV_1 and FVC. However, multivariate analysis done showed that age and duration of employment were significant factors in FEV_1 and FVC while age was only associated with $\%FEV_1/FVC$. Smoking status was not found to be a significant factor. This might be due to the low intensity of smoking among the workers, and no statistical analysis was conducted to differentiate current smokers and ex-smokers in estimating packs and years of smoking. The model of FVC and FEV_1 were explained by 12% and 17% of the independents variables respectively. However, only 5.7% of $\%FEV_1/FVC$ was explained. Height, weight, cigarette equivalent, smoking index, past respiratory illnesses, and past dusty occupations were not included in statistical analysis even though they were the contributing factors to the model of pulmonary function.

This study did not measure the objective dust exposure (respirable dust) or the extent of radiological opacities, which might link to the respiratory symptoms and pulmonary function. The duration of employment was not a good indicator for exposure as there were various categories of steel worker with different level of exposure. This study was conducted among current employed workers. The possibility of selection bias might have arisen from the subjects who had suffered less exposure as compared to those who already left their jobs. Some of them might be due to the illness sustained from the occupational exposure. A number of studies have shown that workers who have resigned or left their job had a higher prevalence of occupational respiratory diseases [18, 19]. The nature of dust exposure was another varying factor that may explain the differences in studies of respirable dust exposed workers [20, 21]. Inorganic compounds rich in iron, nickel, and chromium, are well known in modifying the biological effects of dust exposure.

CONCLUSION

Working in a steel plant was associated with significant respiratory health impairment. There was a possibility that metal dusts were responsible for respiratory symptoms and pulmonary function. It revealed some degree of pulmonary function impairment when compared to the healthy population. A small different change was found over the shift with a decreased value of FEV_1. Age and duration of employment were associated with reported respiratory symptoms and pulmonary function among workers. Further studies are strongly recommended for further evidence of causality.

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REFERENCES

1. El-Zein M, Infante-Rivard C, Malo JL, Gautrin D. Is the metal fume fever a determinant of welding related respiratory symptoms and/or increase bronchial responsiveness? A longitudinal study. *Occupational Environmental Medicine* 2004; **62**: 688-94.

2. Becklace MR, Occupational exposure: Evidence for a causal association with chronic obstructive pulmonary diseases. *American Review of Respiratory Diseases* 1989; 140 (Supp 1) : S85-91.

3. Rodriguez V. Tardon A, Kogeninas M, Preito CS, Cueto A, Garcia M, Memedez IA, Zaplana J. Lung cancer risks in iron and steel foundr workers: A nested case control study in Austria, Spain. *American Journal of Industrial Medicine* 2000; 38:644-50.

4. Hughson, GW, Galea KS, Heim K.E. Characterization and assessment of dermal and inhalable nickel exposures in nickel production and primary user industries. *Annals Journals of Occupational Hygiene* 2010; 54: 8-22.

5. Kondej D, Sosnowski TR. The influence of metal-containing occupational dust on pulmonary surfactant activity. *Chemical Engineering Transactions* 2010. 19:315-19.

6. Ladou J. Occupational and Environmental Medicine. 3rd edition. New York: McGraw-Hill;1997.

7. Xu Z, Brown LM, Pan G-W, Liu T-F, Gao G-S, Stone B-J, Cao R-M, Guan D-X, Sheng J-H, Yan Z-S, Fraumeni JF, Blott WJ. Cancer risks among iron and steel workers in Anshan,, China, Part II: Case-control studies of lung and stomach cancer. *American Journal of Industrial Medicine* 1996; 30: 7-15.

8. Bradshaw LM, Fishwick D, Slater T, Pearce N. Chronic bronchitis, work related respiratory symptoms and pulmonary function in welders in New Zealand. *Occupational Environmental Medicine* 1998;55:150-4.

9. Singh R, Singh HJ, Sirisinghe RG. Sprometric studies among Malaysian among 13 to 69 years of age. *Medical Journal of Malaysia* 1993; 48 (2): 175-84.

10. Chen P-C, Doyle PE, Wang J-D. Respirable dust exposure and respiratory health in male taiwanese steelworkers. *Journal of Industrial Health* 2006;44:190-99.

11. Becklace M. Chronic airflow limitation: its relationship to work in dusty occupations. *Chest* 1988;4:608-17

12. Johnson A, Moira CY, MacLean L, Atkins E, Dybuncio A, Cheng F, Enarson D. Respiratory abnormalities among workers in an iron and steel industry. *British Journal of Industrial Medicine* 1985; 42(2): 94-100.

13. Gomes J, Llyold OL, Norman NJ, Pahwa P. Dust exposure and impairment of lung function in a small iron foundry in a rapidly developing country. *Occupational Environmental Medicine* 2001;58:658-62.

14. Kusaka Y, Iki M, Kumagai S, Goto S. Decreased ventilatory function in hard metal workers. *Occupational and Environmental Medicine* 1996; 53:194-9

15. Pham QT, Mastrangelo G, Chau N, Haluszka J. Five year longitudinal comparison of respiratory symptoms and function in steel workers and unexposed workers. *Bulletin European de Physiopathologie Respiratoire* 1979; 15: 469-80

16. Wang ML, McCabe L, Hankinson JL, Shamssain MH, Gunel E, Lapp NL, Banks DE. Longitudinal and cross sectional analyses of lung function in steel workers. *American Journal of Respiratory Critical Care Medicine* 1996; 153(6):1907-13.

17. Nemery B, Van Leemputten R, Goemare E, Veriter C, Brasseur

L. Lung function measurements over 21 days shift work in steel workers from a stand casting department. *British Journal of Industrial Medicine*. 1985; 42(9):601-11.

18. Fletcher C, Peto R, Tinker C, Speizer FE. The natural history of chronic bronchitis and emphysema: An eight year study early chronic lung disease in working men in London: Oxford University Press; 1976.

19. Ng TP, Phoon WH, Lee HS *et al*. An epidemiological survey of respiratory morbidity among granite workers in Singapore: chronic bronchitis and lung function impairment. *Annual Academy of Medicine Singapore* 1992; 21(3): 312-17.

20. Ravichandran B, Krishnamurthy V. Ravibabu K, Raghavan S, Rajan BK, Rajmohan HR. Assessing dust exposure in an integrated iron and steel plant in south india. *Work* 2000;30:195-200.

21. Rafei M, Gadgil As, Ghole VS, Gore SD, Jaafarzadeh N. Mirkazemi R. Assessment of air pollution on the health status of the workers in beam rolling factory (Iran National Steel Industrial Group) from Ahvaz-Iran. *Indian Journal of Occupational and EnvironmentalMedicine* 2009

22. ;13(1):20-2.