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pulmonary function tests for Respiratory problems of workers in aluminum smelting industry

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Abstract: The aluminum industry is one of the most important and strategic industry in Iran. There are variety of air pollutants in this industry that contribute to respiratory problems in exposed workers. This study was conducted to determine respiratory problems in aluminum smelter workers. A cross-sectional survey of 809 male employees of one Iranian aluminum smelters was conducted in 2015. Total 201 smelters as exposed group and 608 workers from other departments of plants were selected as control group. Information was collected using American Thoracic Society (AT S) standard questionnaire, physical examination and demographic data sheet. Pulmonary function tests were measured for all subjects. The frequency of the respiratory symptoms and signs were not statistically significant between both groups. The mean values of spirometric indices were lower in the exposed workers compared with unexposed group. Regression analysis was performed to evaluate the effects of other variables, in addition to the exposure, age was significantly related with spirometric indices. This study suggests that working in the aluminum smelting plant is associated with reduced pulmonary function tests. Therefore administrators should evaluate these workers with periodic medical examinations and implement respiratory protection program and exposure control inorder to detect and prevent respiratory disorders in the early stages.

Key words: Respiratory, pulmonary function test, aluminum, program, detect

INTRODUCTION

Aluminum is an important industrial metal which is used in the most of industries and this reflects the strategic role of it. This metal with multiple uses is essential in the dynamic global economy. Almost 8% of the earth's crust consists of aluminum, that after oxygen (49.2%) and silica (25.8%) is the most abundant element. (Rosenstock *et al.*, 2005; Farzianpour *et al.*, 2014).

Aluminum is considered as an important industrial raw material and are currently used in the production of aluminum household furniture, doors, windows, facades of buildings, bridges, ships, aircraft, cars, machinery, aerospace industry, military industry, electricity and etc (Lodou and Harisson, 2014). Iran has a strong competitive potential in the aluminum industry because of having rich alumina bauxite mines and also the ability to produce cheap electricity. The method of aluminum production in the plant of our study was industrial electrolysis which is Hall-Heroult process.

Aluminum industry produces a variety of particles, fumes and gases dispersed in the air with the ability to induce a wide range of respiratory disorders (Taiwo, 2014; Abedi *et al.*, 2011). In the reduction process, electrolysis of molten cryolite is used to produce molten aluminum. The main materials in this process are alumina and fluoride. The direct current power which is required for electrolysis is provided by the rectifier.

Under the influence of direct current electricity, aluminum oxide (alumina) is converted to pure aluminum. For the production of aluminum, boiler electrolysis consisting of anode and cathode is used. In this process, cryolite and alumina are acting as the electrolyte and carbon material as an electrode. Molten aluminum

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deposits at the cathode and carbon dioxide gas is often produced at the anode. Hydrogen fluoride and dusts are produced during this process (Kvande and Drablos, 2014).

The most reported respiratory problems among aluminum smelter workers are asthma, bronchitis, irritation of mucous membranes and chronic obstructive pulmonary disease (Rosenstock *et al.*, 2005). Although, it seems that in recent years the incidence of asthma in the smelting of aluminum has been reduced but increase in mortality due to chronic obstructive pulmonary disease and reduced FEV1 }Forced expiratory volume in 1st second (in the melting workers were seen and the casual factor is not known (Kong erud and Soyseth, 2014).

Since, the labor force in this industry are mostly young and in working age, early detection of respiratory diseases and implementing preventive interventions help to maintain a skilled workforce and increase productivity. Similar studies have been done in industrialized countries, also work culture, work processes and weather conditions in our country are different,therefore this study was designed to investigate respiratory problems and pulmonary function tests in the aluminum factory workers in order to prevent respiratory diseases and improve the occupational health of workers.

MATERIALS AND METHODS

This cross-sectional study was conducted among 809 workers in the aluminum industry of Hormozgan province of Iran during 2015. Subjects who were working in smelting part of Aluminum plant were considered as case group and other workers without exposure to respiratory contaminants were selected as control group. Data gathering form including demographic information such as age, sex, marital status, B1141 (Body Mass Index), smoking status and job task, also medical examination form were completed for all workers (Rahmai *et al.*, 2013; Abedi *et al.*, 2014). Respiratory symptoms (cough, sputum and dyspnea on exertion) and respiratory symptoms (hoarseness, wheeze, crackles and tachypnea) of workers were examined by an occupational medicine specialist.

Spirometric parameters including Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), FEV1/FVC, forced expiratory flow at 25-75% of FVC (FEF25-*75)* were measured (Barkhordari *et al.*, 2011).

Pulmonary function tests were carried out by a trained technician using a calibrated by spirometry apparatus (Spirolab 2), between 8-12 a.m. A minimum of three respiratory maneuvers were taken and the best of them was taken according AT S criteria (Pellegrino *et al.*, 2005). Subjects were excluded from the study if they had a history of respiratory diseases such as asthma, bronchitis, emphysema, bronchiectasis, lung cancer... or any other chronic condition in the pre-employment assessment. The study was approved by the ethics committee of Hormozgan University of Medical Sciences. Participants gave written informed consent before the study.

Data were analyzed by SPSS 22 (Chicago USA). Independent sample t test and Chi square test were used for evaluation of quantitative and qualitative variables respectively and regression analysis was done for the assessment of confounders $p<0.050$ has been considered as a significant association.

RESULTS AND DISCUSSION

There were 809 individuals working at aluminum plant at the time of the survey, of whom 608 workers as exposed group and 201 subjects as control group. The average of age and working years of the study population were 35.68+5.08 and 8.32+4.88, respectively. Table 1 describes the frequency of age, B1141 and duration of exposure in both groups. These variables didn't vary significantly between exposed and unexposed groups.

A total of *76* patients (4.9%) were smoker, that didn't vary significantly between study groups. 258 (31.9%) workers reported using personal protective equipment that fewer exposed subjects than unexposed subjects had used personal protective equipment.

Work related symptoms (cough, phlegm and dyspnea) and signs (wheeze, crackle and rhonchi) were reported by relatively few workers, 2.4 and 2.8%,

Table 1: Demographic characteristics and respiratory symptoms and signs in both groups of the study population

Variable (mean±SD)	N (%)	Exposed group	Unexposed group	p value
Age		36.1+4.89	35.51+5.14	0.10
Duration of employment		7.97+3.92	8.44+5.16	0.23
Mil[1]		25.29+3.57	25.57+3.75	0.34
Smoking	Yes	15(7.5)	61(10)	0.27
	No	186(92. 5)	547(90)	
Use of PPE[2]	Yes	82(40.8)	176(28.9)	0.002
	No	119(59.2)	432(71.7)	OR:1.69(1.21-2.35)
Respiratory symptom	Yes	8(4)	21(3.5)	0.72
	No	193(96)	587(96.5)	
Respiratory signs	Yes	9(4.5)	1492.3)	0.10
	No	192(95. 5)	594(97.7)	

'Body Mass Index; [2]Personal Protective Equipment; N =191; N = 608 respectively. There were no significant differences in the proportion of subjects who had symptoms and signs by exposure group.

According to Table 2 mean lung function parameters were higher in unexposed group. Regression analysis adjusting for age, B1141, smoking and duration of employment suggested no statistically significant differences in lung function tests between exposed and unexposed participants except for age and statistically significant association was seen only between FEV1 and duration of employment (Table 3).

This study represents one of the largest studies of the respiratory health of aluminum workers that has been done in Iran. The frequency of respiratory symptoms and signs in the exposed group were 4 and 4.5%, respectively that was not statistically significant with unexposed group, so the results suggest no major effect on respiratory complaints from exposure. In a study which was carried out between bauxite miners in 2001, no significant difference was observed in respiratory complaints and pulmonary function tests (Beach *et al.*, 2001). Another study in Russia has shown that work-related respiratory complaints were 2.9% in aluminum smelters (Maestrelli *et al.*, 2012). Respiratory problems were associated with duration of employment in some studies (Taiwo *et al.*, 2006; Sorgdrager *et al.*, 2000).

This study found significant decrease in lung function tests in exposed subjects compared with unexposed group. In a Swedish aluminum smelters, exposed workers had significantly lower mean FEV1.

Larsson *et al.* (1989) an Australian study found a small decrease in lung function of aluminum smelters. Fritschi *et al.* (2003) other study found a significant doseresponse relationship between lung function and fume exposure in aluminum smelters. Field (1984) Some studies documented reduction in peak expiratory flow values among these workers and reported the incidence of asthma between 0.6-4% (Sjaheim *et al.*, 2004).

The evidence seemed to suggest that fluoride and inspirable dusts are more likely to be responsible for respiratory problems in aluminum smelters (Fritschi *et al.*, 2003; Abramson *et al.*, 2010) although, these workers are exposed to aluminum oxides, carbon, cryolite, poly aromatic hydrocarbon and a small amount of vanadium, chromium and nickel. Rom Markowitz (2007), it is difficult to determine which of these contaminants were most likely to cause respiratory problems, because isolated exposure to only one substance was rare.

In our study a total of 7.5% of exposed subjects were smokers that was not statistically significant between study groups even after regression analysis. This finding may be due to low prevalence of smokers in our paricipants. In a study conducted in 1989, smoking was declared as a major confounding factor (Abramson *et al.*, 1989). In another study, the prevalence of respiratory problems in aluminum smelters were more in smokers (Radon *et al.*, 1999). The survey which was conducted in 2014, concluded that reducing exposure and smoking cessation seems to have a major role in the prevention of respiratory disorders in the aluminum industry workers. Kongerud and Soyseth (2014) studies have been shown lung function decline and chronic airflow limitations in aluminum smelters compared with non- exposed group (Abramson *et al.*, 1989).

Regression analysis was performed to study the effects of other variables on lung function tests. It was observed that in addition to exposure, age is related with decline in all of the spirometric parameters and duration of employment was only associated with FEV1. Pulmonary function tests are dependent on the patient's age, gender and height. Studies in Europe, Australia and New Zealand estimated the annual incidence of 2% with the prevalence of 10% for work-related asthma in workers with more work experience. This study reported after 5 years follow up, respiratory symptoms and bronchial hyperactivity had been improved within 1-2 years and returned to normal values among smelter workers who had been transferred from their job (O'Donnell *et al.*, 1989). A cohort study in Australia and New Zealand has been shown that exposure control, use of respiratory protection and pre-employment

Table 2: Mean lung function values in exposed and unexposed group

Pulmonary function tests	Exposed group (mean±SD)	Unexposed group (mean±SD)	p-value
FVC(Li)	4.12+0.85	4.28+0.66	0.005
FEV1(Li)	3.36+0.68	3.54+0.54	0.000
FEF25-75(Li)	3.62+1.11	3.91+0.97	0.001
FEV1/FVC(%)	81.81+5.92	82.95+5.47	0.013

Table 3: Regression analysis to assess the impact of other variables on pulmonary function tests

	FVC		FEV1		FEF25-75		FEV1/FVC	
Variables		Sig.	B	Sig.	B	Sig.	B	Sig.
constant	4.460	0.000	4.3100	0.000	6.94	0.000	97.080	0.000
Age	-0.130	0.009	-0.033	0.000	-0.105	0.000	-0.522	0.000
Exposure	0.950	0.005	0.1000	0.000	0.149	0.000	0.5410	0.021
BMI	0.003	0.680	0.0050	0.370	0.004	0.631	0. 6600	0.166
Duration of employment	0.009	0.090	0.0080	0.040	0.009	0.137	0.3100	0.388
Smoking	-0.074	0.390	-0.043	0.530	0.035	0.737	0.4540	0.453
R^2		0.020		0.1000		0.2900		0.230

medical examination has a significant reduction in the incidence of occupational asthma in the aluminum workers (Donoghue *et al.*, 2011). Avoiding exposure could improve occupational asthma in less than one-third of cases (Vandenplas *et al.*, 2012).

The advantage of this study include the large sample size, use of standard diagnostic method such as spirometry rather than respiratory questionnaire under the supervision of occupational medicine specialist. Because of the inherent limitations of a cross sectional study design these results need to be interpreted with some caution, also those subjects with a likelihood of developing work related respiratory disorders, might have already left the work. Another limitation was the lack of quantitative exposure assessment of workplace contaminants that could provide a better description of the dose-response relationship.

CONCLUSION

The study found that workplace exposures in aluminum industry (smelting plant) is associated with reduced pulmonary function tests. Therefore, exposure control, use of appropriate respiratory protection and periodic examination of exposed workers is recommended to detect respiratory disorders in the early stages.

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