

Association of Smoking with Chest Radiographic and Lung Function Findings in Retired Bauxite Mining Workers

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Abstract—Inhalation hazards are associated with potentially injurious exposure and increased risk for lung diseases, within the bauxite mining industry, especially for the smelter workers. Smoking is related to decreased lung function and leads to chronic lung diseases. This study had the objective to evaluate whether smoking is related to functional and radiographic respiratory changes in retired bauxite mining workers. Methods: This was a retrospective and cross-sectional study involving the analysis of database information of 140 retired bauxite mining workers from Poços de Caldas-MG evaluated at Worker's Health Reference Center and at the Social Security Brazilian National Institute, from July 1st, 2015 until June 30th, 2016. The workers were divided into three groups: non-smokers (n = 47), ex-smokers (n = 46), and smokers (n = 47). The data included: age, gender, spirometry results, and the presence or not of pulmonary pleural and/or parenchymal changes in chest radiographs. Chi-Squared test was used ($p < 0.05$). Results: In the smokers' group, 83% of spirometry tests and 64% of chest x-rays were altered. In the non-smokers' group, 19% of spirometry tests and 13% of chest x-rays were altered. In the ex-smokers' group, 35% of spirometry tests and 30% of chest x-rays were altered. Most of the results were statistically significant. Results demonstrated a significant difference between smokers' and non-smokers' groups in regard to spirometric and radiographic pulmonary alterations. Ex-smokers' and non-smokers' group demonstrated better results when compared to the smokers' group in relation to altered spirometry and radiograph findings. These data may contribute to planning strategies to enhance smoking cessation programs within the bauxite mining industry.

Keywords—Bauxite mining, spirometry, chest radiography, smoking.

I. INTRODUCTION

BAUXITE is a reddish clay that is refined to produce alumina (Al_2O_3), and reduced to aluminum metal [1].

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Although there is a great interest in the health effects of aluminum on smelting workers [2], there is a relatively small number of studies on the health impact of other areas of the primary aluminum industry, such as bauxite mining [1]-[3]. Workers in bauxite mines participate in the process where bauxite is converted to alumina, and there is exposure to caustic soda and heat [4]. It is speculated that there is an association of this exposure with pulmonary abnormalities which can be evidenced by thoracic radiography and spirometry [1].

Additional hazards to workers in the aluminum industry include biological, chemical, ergonomic hazards, fatigue, and psychosocial factors. Ergonomic risks are minimal because miners are currently highly mechanized. Physical hazards include noise, heat and moisture, vibration, and exposure to ultraviolet radiation. Among the chemical hazards are alumina, bauxite dust, caustic soda and gas exhaust, such as diesel [5].

As in other industrial environments, inhalation represents the most common mechanism of potential lung injury in aluminum production [5]. Respiratory disorders have been described in association with occupational hazards present within the aluminum production industry [5]. The most important symptoms are: cough, sneezing and rhinitis, and these symptoms are accentuated depending on the degree of chronic obstructive pulmonary diseases (COPD). Cross-sectional studies have suggested a more prevalence of respiratory symptoms such as those described above, often correlated with increasing exposure or employment duration [5]. The mortality rate of COPD in aluminum workers has been reported, particularly in relation to those working in less hygienic areas with lack of respiratory protection equipment [5].

Various forms of diffuse parenchymal lung disease have also been associated with aluminum production [6]. Aluminum-induced granulomatous lung disease has also been reported and is distinguished from sarcoidosis by the presence of aluminum and fibrosis within the granulomas. Coexistent exposures to more plausible fibrogenic materials such as asbestos and silica in the primary production work environment are common [5]. It was concluded that, based on the existing human epidemiological data, aluminum is occupationally associated with occurrences of pulmonary fibrosis in susceptible individuals [6], [7].

In addition to respiratory diseases involving bauxite and aluminum miners, studies on the respiratory function of these

employees are equally relevant, but they are relatively scarce. Analysis of spirometry especially forced expiratory volume in the first second (FEV₁) and FEV₁/forced vital capacity (FEV₁/FVC) relation has been used as referential parameters and have a positive correlation between occupational respiratory disease and COPD [3], [7]-[9]. Some studies have demonstrated the importance of spirometry on the evaluation of obstructive pulmonary diseases in longitudinal studies [10]. Thoracic radiography also contributes effectively and inexpensively to confirm pulmonary changes in these individuals [10].

Pulmonary changes may be exacerbated if they are added to smoking or ex-smoking [11]. In addition, the causes of death associated with smoking seem to increase with the number of cigarettes smoked per day [11]. These data have indicated that exposure to mining chemicals may be related to pulmonary function disorders, especially in cigarette smokers [11].

The risk of cancer associated with exposure to aluminum production has been reported in various studies [12]-[16]. In addition, the association of lung cancer and smoking has been well documented in the literature [14], [15], as well as in smoking smelters [16].

Some risk factors may contribute to enhance and exacerbate pulmonary changes such as asthma, smoking or ex-smoking [9]. These data may suggest that exposure to mining irritants and specks of dust may lead to disorders of pulmonary function [9].

Inhalation hazards are potentially associated with injurious exposure and increased risk for lung disease among bauxite workers and smoking is known to decrease pulmonary function [16]. This study aimed to evaluate whether smoking is associated with pulmonary changes in retired bauxite mining workers.

II. METHODS

This was a cross-sectional study involving the collection of information from a database of 140 retired bauxite workers of the Mining Industry from the city of Poços de Caldas - Brazil evaluated at the Worker's Health Reference Center (CEREST) and the Social Security National Institute (INSS). The workers were divided into three groups: smokers (n = 47), non-smokers (n = 47), and ex-smokers (n = 46), being considered a minimum of 5 years smoking cessation for inclusion in the ex-smokers group. The workers were evaluated from July 2015 until June 2016 and submitted to a structured analysis for data collection including: gender, age, spirometric results divided in normal, and altered spirometric testing which include mild, moderate and severe changes based on the VEF1 and CVF references (Table I) [17], [18], presence or not of pulmonary alterations (radiopaque images, pleural abnormalities, nodular calcifications, atelectasis, and other alterations) in the chest x-rays (International Labor Organization) [19], body mass index (BMI), tobacco smoke load (TSL) [20], presence of comorbidities, exposure time to bauxite, and retirement time.

TSL is an indicator of smoking history calculated in pack-years, which is measured by the multiplication of the number of packs of cigarettes smoked each day by the number of years

of use of cigarettes [20]. Since this was a study involving public database information collection, it was not necessary for the analysis through an Ethics Committee. The spirometric exams were performed in a flow metering spirometer, Beatrice brand from EBEM. Measurements of exhaled air volume and expiration time, in addition to the classical parameters of spirometry, were made using Pulmosoft 4.0 software. The tests were performed in the same time period, from 7 am to 10 am. The radiographic evaluations were made by radiologists, in the number of two, and always by the same professionals.

TABLE I
CLASSIFICATION OF SPIROMETRIC SEVERITY IN PATIENTS WITH FEV₁/FVC < 0,70

Severity:	Spirometric Dysfunction:
Mild	FEV ₁ > 80%
Moderate	50% ≤ FEV ₁ < 80%
Severe	30% ≤ FEV ₁ < 50%

FEV₁: forced expiratory volume in the first second. FVC: forced vital capacity.

For the statistical analysis, it was applied the Chi-Squared test for the data analysis with $p < 0.05$ using the Prism 6, version 6.01 for Windows (GraphPad Software Inc.) [21]. In order to describe the profile of the sample according to the various variables under study, a table of descriptive statistics of the variables was elaborated.

III. RESULTS

All retired workers were male with a total mean age of 62 years-old ranging from 49 to 77 years-old. The mean age of ex-smokers was 61.5 years-old, 61.8 years-old for smokers and 62.5 years-old for non-smokers. There was no significant difference between groups, with $p > 0.05$. Calculated using Kruskal-Wallis Test ($p = 0.5412$) [21]. 33.6% were smokers, 33.6% non-smokers, and 32.8% ex-smokers. In the smokers' group, 17% had normal spirometry while 83% of tests were altered, 53% with mild changes, 19% with moderate and 11% with severe changes in spirometric findings. Also demonstrated in this group, 36% had normal and 64% had altered chest x-rays. In the non-smokers' group, 81% had normal spirometry, 19% of tests were altered changes. In this same group, 87% had normal and 13% had altered chest x-rays. In the ex-smokers group, 65% had normal spirometry, 35% of tests were altered, 11% with mild, 9% with moderate and 15% with severe changes in spirometric findings. Also, in this group, 70% had normal and 30% had altered chest x-rays. In this group, the mean time of smoking cessation was 26 years.

The BMI varied from 18.6 up to 29.4 with a total mean value of 25.0 kg/m², divided in the following groups: smokers' group: 23.5 kg/m², ex-smokers: 24.6 kg/m², and non-smokers: 26.5 kg/m². The mean TSL was 20.6 years/pack for the ex-smokers' group and 36.5 years/pack for the smokers' group. These results for both BMI and TSL were not statistically different (Kolmogorov-Smirnov Test, with $p = 0.06$) [21].

No comorbidities that could interfere with the spirometric results were found. Some of the workers were under treatment

for hypertension (28%) and diabetes (10%) but their clinical status was under control and these diseases were not shown to interfere with the spirometric results (Kolmogorov-Smirnov Test, with $p = 0.06$) [21]. The more severe spirometric changes were verified only in the smokers and ex-smokers, the last being the group with the most severe alterations. All results were statistically significant, except for the mild changes in the non-smokers' and ex-smokers' groups (Table II).

TABLE II

SPIROMETRY AND CHEST RADIOGRAPHY FINDINGS IN RETIRED BAUXITE MINING WORKERS IN THE 3 GROUPS: SMOKERS, NON-SMOKERS, AND EX-SMOKERS

	Smokers	Non-Smokers	Ex-Smokers
Number of Workers (%)	47 (33.6%) ^a	47 (33.6%) ^a	46 (32.8%) ^a
Normal Spirometry (%)	8 (17%) ^a	38 (81%) ^c	30 (65%) ^b
Altered Spirometry (%)	39 (83%) ^c	9 (19%) ^a	16 (35%) ^b
Mild Changes in Spirometry (%)	25 (53%) ^b	6 (13%) ^a	5 (11%) ^a
Moderate Changes in Spirometry (%)	9 (19%) ^c	3 (6%) ^a	4 (9%) ^b
Severe Changes in Spirometry (%)	5 (11%) ^b	0 (0%) ^a	7 (15%) ^c
Normal Chest X-Ray (%)	17 (36%) ^a	41 (87%) ^c	32 (70%) ^b
Altered Pulmonary Findings in Chest X-Rays (%)	30 (64%) ^c	6 (13%) ^a	14 (30%) ^b

The values refer to the total number and percentages.

Data are presented by frequency (percentage). Statistical analyses are performed by χ^2 (Chi-Squared). Different over script letters mean a significant difference between the groups. $P < 0.001$. The different letters were used to mark different groups, that is, groups that were statistically different. If for the same factor (line), they have one or more equal letters (in the columns); this indicates that those with the same letters are not different from each other. In addition, the letter ^a was standardized for the lowest values, letter ^b for intermediate values and letter ^c for the highest values.

All the alterations found in the spirometry tests were related to being obstructive for all three groups. There were no restrictive patterns found for any of the mining workers tested during the study.

All the workers were bauxite retired miners who were exposed to bauxite dust at work. The exposure time to bauxite dust ranged from approximately 15 to 20 years for all three groups. The results also have shown a mean age of 17.7 (± 1.5) years for the smokers' group, 18.3 (± 1.1) years for the ex-smokers' group, and 18.1 (± 1.1) for the non-smokers' group. These differences were not statistically significant among all the three groups evaluated [21].

The retired workers were followed up for a period of time that ranged from 5 to 15 years after retirement. The mean time after retirement for all three groups was: 9.5 (± 5.4) for the smokers' group, 10.3 (± 5.1) years for the ex-smokers' group and 10.1 (± 4.2) for the non-smokers' group. These variations among all the three groups were not statistically significantly different [21].

The chest x-rays alterations included many pulmonary non-pneumoconiotic findings which were listed in Table III for each group. Non-pulmonary alterations such as the atherosclerotic aorta or other non-pulmonary related

alterations were not included in the study.

TABLE III
PREVALENCE (%) OF RADIOGRAPHIC ALTERATIONS FOR ALL THREE GROUPS
USING DE ILO CLASSIFICATION

	Radiographic alterations	Prevalence (%)
Smokers group	Calcified non-pneumoconiotic nodules (e.g. granuloma) or nodes	70%
	Ill-defined diaphragm border	15%
	Plate atelectasis	5%
	Round atelectasis	5%
Ex-smokers group	Calcified non-pneumoconiotic nodules (e.g. granuloma) or nodes	71%
	Ill-defined diaphragm border	19%
	Plate atelectasis	9%
Non-smokers group	Calcified non-pneumoconiotic nodules (e.g. granuloma) or nodes	100%

IV. DISCUSSION

The present study has dealt with retired workers in bauxite miners, which serve as the starting point for the production of aluminum metal. Some of the risks that these miners represent are already well established in the literature [5], [22].

Regarding the chest radiographs of the bauxite mining workers analyzed in this study, non-smokers presented the highest percentage of radiographs without alterations (87%), while 64% of smokers had alterations in their chest radiographs. These results are somewhat similar to those of some authors in the literature. One of those studies conducted a cross-sectional investigation with 788 male employees at an aluminum production company and examined the relationship between radiographic changes in smokers and exposure to dust from bauxite refineries [22]. The radiographic changes predominated in the smokers' group ($p < 0.001$) and there was a moderate increase in pulmonary radiographic opacity in the group of non-smokers with increased cumulative exposure ($p < 0.001$) [23]. On the other hand, another study concluded that exposure to bauxite dust in the aluminum industry was not related to respiratory symptoms or consistent respiratory dysfunction, in a longitudinal investigation for 13 years following the relationship between pulmonary injury and inhalation of bauxite dust [3].

Other authors have aimed to examine the association between exposure of bauxite dust and alumina, cancer incidence and mortality of respiratory and circulatory diseases in bauxite miners and alumina refinery workers. The results from the study have suggested that exposure to inhalation of bauxite dust may be associated with excess risk of death from nonmalignant respiratory disease and cumulative inhalation of alumina dust may be associated with excess risk of cerebrovascular disease death. No exposure appeared to increase the risk of cancer incidence [24].

Some other authors evaluated the morphological, etiological and clinical effects related to COPD and asthma, due to exposure of workers in the aluminum industry. It was demonstrated that there was substantial evidence of asthma (with a decline over 10 years) and increased COPD mortality and decreased FEV1 in these workers. They concluded that

reduction of exposure and cessation of smoking suggest the greatest preventive measure to avoid respiratory injury in the aluminum industry [7].

Some of the factors that could have interfered with our results are associated probably with the restricted number of individuals for each group. Those former retired workers are hard to be found and followed up. Our study was performed in a homogenous group mainly associated with the fact that most workers were from the same company that had a strong preventive health promotion culture influence on their employees. This may explain the lack of obese workers and comorbidities among de employees.

Some literature reviews have concluded that there are many studies on occupational hazards to health and risks in the primary aluminum production industry. Based on a number of environmental and technological factors, some of these risks may, in specific circumstances, also extend to local communities. They also suggest that rigorous health protection programs must be implemented throughout the industry to control, as far as possible, imminent risks and dangers related to the aluminum industry [5]. The International Aluminum Institute (IAI) Health Committee has been the great facilitator in the continuous improvement of technology to protect workers in the aluminum industry and people in local communities [5].

V.CONCLUSION

These results demonstrated a large difference between the smokers' and non-smokers' groups in regard to spirometric and radiographic pulmonary alterations. The smokers accounted for 83% altered spirometric tests and almost 64% altered pulmonary findings in the chest radiographs, while non-smokers had 19% of altered spirometric and only 13% of altered radiographic exams. The former smokers' group also had an improved result compared to the active smokers' group having 70% of the cases with normal chest x-rays regarding pulmonary findings and 35% of altered spirometric tests. These data may contribute with strategies to enhance smoking cessation programs within the mining industry in order to prevent a reduction of pulmonary changes and possibly decrease the risk of developing lung diseases in smelter workers.

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