ORIGINAL ARTICLE

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Assessment of the biological effects of exposure to toxicants among workers at a metallurgical company in Caxias do Sul, RS, Brazil

Avaliação dos efeitos biológicos da exposição a toxicantes em trabalhadores de uma metalúrgica de Caxias do Sul, RS

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ABSTRACT | Background: Metallurgical workers are a high-risk population as a function of their occupational exposure to toxicants, such as heavy metals, aromatic hydrocarbons and silicate. **Objective:** To investigate the occurrence of biological effects among workers exposed to toxicants in various areas of a metallurgical company in Caxias do Sul, Rio Grande do Sul, Brazil. **Methods:** Cross-sectional study with 31 workers from 10 areas who responded a questionnaire on occupational and lifestyle habits. Blood and toxicology tests were compared to the questionnaire results. **Results:** About 19.4% (n=6) of the sample did not use all the required personal protective equipment (PPE). Reduction of red blood cell parameters and leukocyte abnormalities were found, including leukocytosis, neutrophilia and eosinophilia, as well as in the blood lead levels. The following significant associations were found on analysis per work area: smoking and neutrophilia (p=0.000); work in the mold section and leukocytosis (p=0.023) and eosinophilia (p=0.007); and more than 10 years of work and leukocytosis (p=0.008). **Conclusions:** The data suggest that length of work, type of exposure and use of PPE might cause changes in the results of laboratory tests.

Keywords | occupational exposure; laboratory research; personal protective equipment; metallurgy.

RESUMO | Introdução: Metalúrgicos compõem uma população de risco pela sua exposição ocupacional a toxicantes, como metais pesados, gases, hidrocarbonetos aromáticos e silicato. **Objetivo:** Avaliar a existência de efeitos biológicos em trabalhadores expostos a toxicantes de vários setores de uma metalúrgica de Caxias do Sul, Rio Grande do Sul. **Método:** Foi realizado um estudo transversal com 31 trabalhadores de 10 setores em que foi aplicado um questionário sobre hábitos ocupacionais e de vida. Exames hematológicos e toxicológicos foram comparados com os resultados do questionário. **Resultados:** 19,4% (n=6) dos trabalhadores não usaram todos os equipamentos de proteção individual (EPIs). Foi possível observar diminuição dos parâmetros do eritrograma e alterações na série branca, como leucocitose, neutrofilia e eosinofilia, e no chumbo sérico. Evidenciaram-se valores diminuídos na série vermelha e leucocitose dos trabalhadores que não faziam uso adequado dos EPIs. Quando avaliado o setor de trabalho, pôde-se evidenciar as seguintes associações significativas: fumantes e neutrofilia (p=0,000); setor da moldagem e leucocitose (p=0,023) e eosinofilia (p=0,007); mais de 10 anos de trabalho e leucocitose (p=0,008). **Conclusões:** Os dados sugerem que o tempo de trabalho, o tipo de exposição e o uso de EPIs podem alterar exames laboratoriais.

Palavras-chave | exposição ocupacional; investigação laboratorial; equipamento de proteção individual; indústria metalúrgica.

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INTRODUCTION

The city of Caxias do Sul, Rio Grande do Sul, Brazil, succeeded in adjusting itself to the expansion of industry to become the seat of large industrial companies, for example, in the metallurgy sector, which represent a significant fraction of the local manufacture[1]. Workers at such companies compose a high-risk population, because the use of personal protective equipment (PPE) notwithstanding, they are exposed to definite, mainly physical (melting furnaces, e.g.) and chemical (metal fumes and other suspended particulates, like silica and coal) agents. As a result, they are more susceptible to harm and more prone to develop diseases[2,3].

The chemicals present in foundries include heavy metals (lead, nickel, copper and tin); organic pollutants (dioxins; carbon monoxide and other metal fumes; aromatic hydrocarbons, such as xylene, benzene, toluene and ethylbenzene; and carbon black, namely, soot released during painting); and silicate and coal dust originated in the casting and grinding of metallic parts[3-6]. In 2014, the Ministry of Labor and Employment classified these substances as potential toxicants. Chromium (VI) and nickel compounds, soot, iron fumes, crystalline silica, benzene and other pollutants were recognized as carcinogens. In turn, inorganic lead was defined as probable, and lead, ethylbenzene and carbon black as possible carcinogens[7].

Daily exposure to the aforementioned carcinogens might cause several forms of acute and/or chronic damage, the effects of which on the body vary as a function of age, sex, previous diseases, previous exposure, current level of exposure and use of PPE[8]. While PPE affords workers relative protection against chemicals, the latter still pose risk of toxicity even when PPE is correctly used[3]. In addition, as is known, many workers fail to use protective equipment due to careless, ignorance of the hazards to which they are actually exposed, discomfort, lack of training and incentive by employers, or unavailability[9]. Facing this scenario, a task of occupational toxicology is to measure such daily exposure, e.g., by monitoring the levels of toxicants among exposed individuals.

As is known, the abovementioned harmful effects might be assessed on periodic examinations, as recommended by the Occupational Health Medical Control Program (Programa de Controle Médico de Saúde Ocupacional — PCMSO) in which context laboratory tests are frequently performed[10]. However, several lifestyle factors, such as diet, physical activity and use of medication, for instance, influence the results of laboratory tests[11]. Based on these considerations, the aims of the present study were to compare differences in occupational exposure and use of PPE among workers at a foundry in Caxias do Sul, and to investigate the presence of biological effects on individuals exposed to toxicants in the various company areas through analysis of the results of the latest periodic laboratory tests performed as a part of PCMSO.

METHODS

The present study was approved by the research ethics committee of Fátima Education School, Rio Grande do Sul, ruling no. 1,375,012, from 24 March 2016.

SAMPLING AND QUESTIONNAIRE APPLICATION

The present was a cross-sectional retrospective study of a population selected by convenience sampling. The sample comprised 31 employees of a foundry located in Caxias do Sul, Rio Grande do Sul, allocated to the following areas: mold, melting, grinding, painting, maintenance, shipping, transportation, laboratory of analysis of metallic alloys, storage and cleaning. Initially 65 employees were interviewed, but 31 were excluded due to lack of results for complete blood count in their occupational examination records, and further three for failing to provide information on their body weight and height (for calculation of the body mass index — BMI) upon responding the questionnaire.

After they read and signed an informed consent form, all the participants responded a questionnaire on personal and occupational health (based on the model recommended by the International Commission for Protection against Environmental Mutagens and Carcinogens — ICPEMC)[12] concerning exposure to toxicants. They also responded the Brazilian version of the Drug Use Screening Inventory (DUSI) — part 1,

developed and adapted by Micheli and Formigoni[13] and Micheli and Sartes[14] for screening of substance abuse among adolescents; this questionnaire was applied by one of the investigators. The participants also granted access to the data on their latest periodical examination performed by the employer.

The aforementioned questionnaire included personal (age, sex, body weight, height, smoking, alcohol consumption, use of drugs, history of liver, kidney and hematopoietic system disorders) and occupational (work area, length of work, previous jobs in the metallurgy sector, rest breaks, daily and weekly working hours, use and frequency of use of PPE including safety footwear, safety helmets, coats, gloves, respiratory protection, glasses and protective hearing devices) data. The data on body weight and height were self-reported; BMI was calculated as per the parameters formulated by the World Health Organization[15].

LABORATORY TESTS

We also collected data relative to the latest periodical laboratory tests, including: complete blood count (n=31), serum lead (n=17) and carboxyhemoglobin (n=19). These tests were performed by a laboratory hired by the employer in the second semester of 2015, except for two cases, in which testing was performed in 2013 and 2014, respectively. This difference in dates resulted from the periodicity of testing, which is defined according to the function performed by employees as established in the company's PCMSO in compliance with Regulatory Standard (RS) no. 79.

Complete blood count was performed on total blood added the anticoagulant agent ethylenediaminetetraacetic acid (EDTA) by means of automated analyzer Sysmex XS — 1000i. Lead was measured on total blood added EDTA (Trace tube) by means of inductively coupled plasma mass spectrometry (ICP-MS). Carboxyhemoglobin was measured on total blood added EDTA with a T60 UV spectrophotometer. The reference values were provided by the laboratory. In regard to control of quality, the laboratory was accredited certificates ABNT NBR ISO 9001:2000 and of Excellence by the External Quality Assessment Program (Programa de Avaliação Externa da Qualidade — PNCQ).

STATISTICAL ANALYSIS

Statistical analysis was performed with software *IBM SPSS* version 20. Descriptive analysis included calculation of absolute and relative frequencies for qualitative variables and of mean and standard deviation (SD) for quantitative variables. The χ^2 test and adjusted residuals analysis were performed to investigate associations between variables. The 95% confidence interval (95%) was considered to be significant[16].

RESULTS

PERSONAL HABITS

The absolute and relative frequencies for the participants' personal data are described in Table 1. The average age of the sample was 39.93 years old (±9.64); 29 (93.5%) participants were male.

Most participants, 15 (48.4%) exhibited overweight. Twenty-three (74.2%) participants reported to be non-smokers, and 16 (51.6%) not to consume alcohol (while consumption of any kind of alcoholic beverage was considered, only wine and beer were explicitly mentioned). Two (6.4%) participants reported occurrence of chronic diseases, being one case of diabetes and one of hepatitis. Only one (3.2%) participant reported to use drugs. Five (16.1%) participants made continuous use of medications.

OCCUPATIONAL HABITS

In regard to the employment history (Table 2) the last job for 10 (33.3%) participants had been at a metallurgy company, having been allocated to the mold, melting, mechanical maintenance, electrical maintenance and other (as transportation and laboratory) areas. In regard to their current job, 1 (3.2%) participant was allocated to the mold area, 1 (3.2%) to grinding, 3 (9.7%) to painting, 9 (29.0%) to mechanical/electrical maintenance, 10 (32.3%) to melting and 7 (22.6%) to other areas, including storage, cleaning, shipping, transportation and laboratory.

Most participants, 11 (35.5%), had worked at the company for 1 to 3 years. Only 10 (33%) participants had previously worked at another area in the same company.

Twenty-one (67.7%) participants worked 5 times per week. The daily working hours were over 8 hours (specifically, 8 hours and 40 minutes) in most cases, 18 (58.1%). All the participants reported to be granted rest breaks.

Table 1. Personal health history of metallurgical workers, Caxias do Sul, 2017 (n=31).

	n	%
Age range (years old)		
20 to 29	5	16.1
30 to 39	10	32.3
40 to 49	12	38.8
50 to 64	4	12.9
Male	29	93.5
Female	2	6.5
Body mass index		
Ideal weight	11	35.5
Overweight	15	48.4
Grade 1 obesity	5	16.1
Smoking		
Non-smokers	23	74.2
Less than 1 pack per day	7	22.6
More than 3 packs per day	1	3.2
Alcohol consumption		
Non-drinkers	16	51.6
1 to 4 glasses per week or less	13	41.9
5 to 8 glasses per week	2	6.5
Type of alcoholic beverages		
Beer	12	38.7
Beer and wine	3	9.7
Chronic diseases		
None	29	93.5
Diabetes	1	3.2
Hepatitis	1	3.2
Drug use		
Non-users	30	96.8
Users	1	3.2
Continued medications		
No	26	83.9
Yes	5	16.1

Table 2. Occupational history of interviewed employees, Caxias do Sul, 2017 (n=31).

	n	%
Last job at a metallurgical company		
Yes	10	33.3
No	21	66.7
Length of exposure (last job)		
Up to 5 months	1	3.2
1 to 2 years	1	3.2
2 to 3 years	1	3.2
3 years or more	7	22.6
Current company area		
Mold	1	3.2
Grinding	1	3.2
Painting	3	9.7
Maintenance	9	29
Melting	10	32.3
Other[1]	7	22.6
Length of work in current area (years)		
Up to 1	6	19.4
1 to 3	11	35.5
3 to 5	4	12.9
5 to 10	4	12.9
More than 10	6	19.4
Previously worked in other area		
No	21	67.7
Mold	5	16.1
Melting	2	6.5
Grinding	1	3.2
Machining	1	3.2
Engineering	1	3.2
Weekly frequency in current area		
5 days per week	21	67.7
6 or 7 days per week	10	32.3
Daily working hours		
>8 hours	18	58.1
Equal to 8 hours	13	41.9
Use of required PPE[2]		
Yes	25	80.6
No	6	19.4
Daily duration of PPE use		
Full shift	22	71
6 to 7 hours	5	16.1
3 to 5 hours	3	9.7
<1 hour	1	3.2

PPE: personal protective equipment; [1]other: storage, cleaning, shipping, transportation and laboratory; [2]PPE required as per area exposure

Twenty-five (80.6%) participants used the required PPE (as per the characteristics of exposure in each factory area), while 6 (19.4%) did not use the PPE essential for their functions. Twenty-two (71.0%) participants used PPE all along the full shift, 5 (16.1%) 6 to 7 hours, 3 (9.7%) 3 to 5 hours and 1 (3.2%) less than one hour. The latter's job involves handling forklifts. Among the participants who used PPE 3 to 5 hours per day, 2 were allocated to mechanical and electrical maintenance and 1 to melting. All these employees ought to use PPE all along the full shift as a function of their exposure to fumes, particulates, and also to noise. One (3.2%) participant described PPE as uncomfortable, and another (3.2%) stated that he did not see the need to use it.

LABORATORY TESTS

Red blood cells

Relative to the full sample (n=31): the red blood cell (RBC) count was below the reference values (RV) in 3 (9.7%) cases; the hemoglobin (Hb) level was low in 2 (6.5%); the hematocrit (HCT) was reduced in 3 (9.7%); the mean corpuscular hemoglobin (MCH) elevated in 7 (22.7%) cases and 1 (3.2%) with the parameter decreased; the mean corpuscular hemoglobin concentration (MCHC) low in 2 (6.5%). Borderline association was found between length of work of 3 to 5 years and low HCT (p=0.057).

White blood cells

Relative to the 31 participants, 3 (9.7%) cases of leukocytosis, 2 of eosinophilia (6.5%) and 4 (12.9%) of neutrophilia were found. Significant association was found between: non-smokers and normal segmented neutrophil levels and between smokers (less than 1 pack per day) and neutrophilia (p=0.000); work in the mold area and leukocytosis (p=0.023), eosinophilia (p=0.007) and lymphocytosis (p=0.000); and length of work of 10 years or more and leukocytosis (p=0.008).

Lead

Data on blood lead levels were available for 17 participants allocated to the following areas: mold (n=1), melting (n=7), painting (n=1), grinding (n=1), maintenance (n=6) and other (n=1). The highest average serum lead levels corresponded to employees allocated to the painting (13.90±0 mcg/dL) and melting (9.92±5.35 mcg/dL) areas. However, significant association was not found of the lead levels with work area (p=0.391) or any of the analyzed hematologic parameters: RBC count (p=0.288); Hb (p=0.261); HCT (p=0.261); mean corpuscular volume (MCV) (p=0.224); MCH (p=0.333); MCHC (p=0.288); red cell distribution width (RDW) (p=0.243); platelets, total leukocytes, segmented neutrophils, lymphocytes or monocytes (p=0.248); eosinophils (p=0.333); or basophils (p=0.333).

Carboxyhemoglobin

Data on carboxyhemoglobin levels were available for 19 participants. The average level was 0.84±0.22% (within RV). Significant association was not found between carboxyhemoglobin levels and work area (p=0.823).

The mean and SD of the blood test results (n=31) distributed per work area are described in Table 3, and the ones of the blood lead levels in Table 4. The average results of the blood tests were within the normal values as a whole.

DISCUSSION

HEALTH HABITS

Males predominated among the employees, which agrees with the results of other studies conducted with metallurgical workers[17-19]. The number of participants who reported to consume alcohol was higher than the one of smokers; 13 (41.9%) stated they drank 1 to 4 glasses per week, and 2 (6.5%) 5 to 8 glasses. The potential toxicity of alcohol is well known, particularly in regard to the liver[4]. Among the participants who reported to consume alcohol, 12 (38.7%) drank beer and 3 (9.7%) beer and wine. Also a study conducted with metallurgical workers from the interior of the state of São Paulo found predominance of drinkers and higher consumption of beer[17].

No less relevant, a considerable proportion of the participants exhibited overweight (n=15; 48.4%). This finding agrees with the results of another study conducted in the same geographical area, which evidenced higher prevalence of workers with inadequate dietary habits associated with higher odds of development of fatty liver[19]. A large proportion of the metallurgical workers analyzed by Battaus and Monteiro[17], 41.75%, exhibited overweight or obesity.

OCCUPATIONAL HABITS

The largest proportion of participants worked in the melting area (n=10; 32.3%), followed by mechanical/electrical maintenance (n=9; 29.0%). Therefore, relative to the total sample, occupational exposure to toxicants such as metal fumes (heavy metals — lead and cadmium) prevailed, as a peculiar characteristic of the melting process. To this we should add inhalation of particles of silica, coal and associated and still volatile metals, such as hydrocarbons, in the case of the workers allocated to the maintenance department, since they perform their work in all the factory areas, which thus characterizes mixed exposure[7,20].

While most participants worked 5 days per week (n=21; 67.7%) in most cases the daily working hours were over 8 hours (8 hours and 40 minutes) (n=18; 58.1%). Most participants reported adequate use of PPE (as a function of the characteristics of exposure in each area) but 6 did not, i.e., they did not use all the equipment pieces required for the performance of their activities. The least used PPE pieces were face masks and hearing protection devices. Two (6.4%) among such workers gave justifications for their behavior: 1 (3.2%) stated that PPE was uncomfortable, and the other (3.2%) that he did not see any need for it. The employer distributes PPE as per the function needs, but not all employees adhere to its use[20]. According

Table 3. Laboratory parameters per company area, Caxias do Sul, 2017 (n=31).

Parameters	Mold (n=1)	Melting (n=10)	Painting (n=3)	Grinding (n=1)	Maintenance (n=9)	Other (n=7)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Red blood cells (millions/mm³)	5.01±0	5.23±0.42	4.84±0.2	5.32±0	5.11±0.37	4.96±0.59
Hemoglobin (g/dL)	15.90±0	15.08±0.89	14.53±0.80	14.20±0	15.34±0.79	14.6±1.65
Hematocrit (%)	47.60±0	44.5±2.88	42.47±1.67	45.20±0	45.32±2.50	42.51±4.18
MCV** (fL)	95.00±0	85.29±3.09	87.7±6.18	85.00±0	88.85±4.17	86.01±4.58
MCH** (pg)	31.70±0	28.93±1.59	30.03±2.38	26.70±0	30.09±1.48	29.49±1.55
MCHC** (g/dL)	33.40±0	33.91±1.17	34.2±0.62	31.40±0	33.87±0.99	34.3±0.65
RDW*** (%)	13.70±0	12.95±0.85	13.2±0.53	14.50±0	12.96±0.63	13.36±0.52
Total leukocytes (/mm³)	11090.0±0*	8118±2291.94	9343.3±2473.57	4700.00±0	7697.78±1754.64	6618.57±1311.04
Eosinophils (/mm³)	1785.00±0*	270.7±239.64	187.8±71.60	47.00±0	163.2±86.57	184.39±82.63
Segmented (/mm³)	3837.00±0	4518.9±2142.79	5663.07±1960.42	1880.00±0	4329.3±1290.64	3799.51±1158.93
Band cells (/mm³)		158.0±0		94.00±0		57.00±0
Limphocytes (/mm³)	4436.00±0*	2669.2±634.07	2682.87±667.93	2444.00±0	2529.67±626.64	2084.26±427.12
Monocytes (/mm³)	976.00±0	618.8±138.64	781.65±100.17	235.00±0	646.78±141.79	509.24±168.55
Basophils (/mm³)	55.00±0	24.9±17.46	27.94±7.54	0.00±0	28.89±15.95	32.75±32.55
Platelets (10³/mm³)	251.00±0	239.6±53.13	254±30.51	203.00±0	252.78±65.81	266.14±90.81

Values with significant increase and p<0.05 on the χ^2 test and adjusted residuals analysis. **MCV: mean corpuscular volume; MCH: mean corpuscular hemoglobin; MCHC: mean corpuscular hemoglobin concentration; RDW: red cell distribution width.

Table 4. Blood lead levels per factory area, Caxias do Sul, 2017 (n=31).

Tests	Mold (n=1)	Melting (n=7)	Painting (n=1)	Grinding (n=1)	Maintenance (n=6)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Lead (mcg/dL)	2.00±0	9.92±5.35	13.95±0	1.9±0	5.23±0.84

to RS 6, PPE is meant to protect workers from hazards that threaten their health and safety at work, and supply is mandatory[21]. Lombardi et al.[22] identified several factors that might enhance the use of PPE by workers, such as: improved comfort and availability, resistance to damage, incentives, training and exposure warnings.

LABORATORY TESTS

MCV, RDW, platelet, leukocyte, band cell, monocyte and basophil count were within the limits normal and did not exhibit significant association with any of the investigated variables ($p>0.05$). Interestingly, 2 out of the 6 the participants who reported not to make adequate use of PPE exhibited a low RBC count; in addition, one exhibited low Hb and HCT, and the other neutrophilia. The neglected PPE pieces were gloves, face mask and hearing protection devices.

The results evidenced reduced RBC count, Hb, HCT, MCH and MCHM. These findings might be explained by the workers' exposure to toxicants such as lead and hydrocarbons (toluene, xylene and benzene). Lead is not only present in metal fumes in the melting area, but is also a component of coal dust, together with other metals and substances, including copper, arsenic, aluminum, iron, zinc and silica; coal dust is most abundant in the mold area[23]. In addition to causing neurologic and kidney disorders, lead interferes with the hematopoietic system, more particularly with hemoglobin synthesis by inhibiting the activity of the enzymes involved in the heme biosynthesis[24]. This type of disorder was investigated in the study by Ibeh et al.[25] conducted with employees of a gas station. The results evidenced reduced Hb, HCT, MCH and MCHM levels (relative to RV) among auto mechanics (who handle lead-containing compounds, as e.g., in paint sprayers) compared to controls (who exhibited normal blood test parameters).

Hydrocarbons (benzene, toluene and xylene) are components of the paints used in the painting area. The mutagenic potential of these compounds has been recognized, and exposure is associated with abnormalities detected through other laboratory tests, such as measurement of gamma-glutamyl transferase, aminotransferases, urea, creatinine, albumin and total proteins[5,26,27]. A known myelotoxic agent, benzene affects erythrocytes, leukocytes and platelets, respectively causing anemia, polychromasia, basophilic stippling and peripheral erythroblasts, lymphopenia and thrombocytopenia[28].

In their studies, Abou-Elwafa et al.[29] and Brucker et al.[26] found significant reduction of the RBC count, Hb and HCT among gas station employees exposed to hydrocarbons (such as xylene and toluene). These findings corroborate the results of the present and Ruiz et al.'s study[28]. Abou-Elwafa et al.'s[29] findings are further similar to ours, since we found borderline association between 3 to 5 years of exposure and reduced HCT ($p=0.057$) and those authors between significant decrease of this same parameter and 10 years of average occupational exposure.

Although detected in one single case, the strong association among leukocytosis, lymphocytosis and eosinophilia in a worker allocated to the mold area might be due to exposure to free silica, which as was mentioned, is a component of the coal used in this area. Other possible associations were ruled out, because the involved employee had no chronic disease and made proper use of PPE. Workers handle a mix of particles including sand and coal dust in the preparation of the molds into which molten metal at high temperature is poured. Handling of this compound results in dispersion of its particles in the air, under which circumstances it might be inhaled by workers. Not even the use of face masks grants full protection against this hazard[3]. As is known, coal is associated with considerable genotoxicity, by increasing reactive oxygen species (ROS) and interfering with the mechanisms of DNA repair[30]. In a study with construction workers exposed to cement dust and silica, Mandal and Suva found significant reduction of Hb, HCT and MCV, and also significant increase of MCHM and the eosinophil count by comparison to a control group. Eosinophilia is associated with parasitic infections, but also with lung diseases, as the ones which occur as a result of exposure to silica, i.e., silicosis[31-33]. In a study also conducted with workers exposed to cement dust, Jude et al.[34] detected leukocytosis and lymphocytosis, which agrees with the results of the present study. However, we should observe that excessive leukocyte elevation might occur even after short periods of exposure and in association with several factors, such as presence of diseases, age, sex and ethnicity[34,35].

The significant association between work for more than 10 year at the company and leukocytosis ($p=0.008$) can also be included within the context to exposure to

toxicants, as a result of inflammation secondary to chronic exposure. Significant association was also found between smoking (less than one pack per day) and neutrophilia (p=0.000) while the count of segmented neutrophils was normal among non-smokers. This association between neutrophilia and smoking is described in the literature, the number of leukocytes being higher among smokers compared to non-smokers[35,36]. However, many factors interfere with the peripheral neutrophil count, such as sex, age, ethnicity and disease[35]. Neutrophilia is explained by inflammation caused by the inhaled smoke and involves several mechanisms of action. For instance, interaction with the ROS in smoke and activation of inflammatory reaction through stimulation of the pulmonary macrophages, which releases mediators and further ROS, thus increasing the number of neutrophils[37].

Blood lead was measured for only 17 workers in the analyzed sample (n=31) within the context of PCMSO. The employer did not request this test for all the employees in the areas with highest exposure to lead (melting and painting, for instance). The probable reason was employer's neglect, but perhaps also the idea that there was no exposure whatsoever. We also found that the workers allocated to the painting and melting areas exhibited the highest blood lead levels. This relationship was also evidenced in another study, which results showed higher exposure to metals, specifically lead, among workers allocated to the melting area[38]. This finding confirms that exposure to metals is stronger in the melting area and shows that use of PPE (face mask specifically) is indispensable. Moreover, we found that two among the workers allocated to the melting area (n=10) did not adhere to the use of face mask. Therefore, although most metallurgical workers in this area complied with PPE use, a part of the workers is still exposed to toxicity.

The present study has some limitations. First, the sample size was small as a result of the exclusion criteria applied. Then, the distribution of occupational tests among the participants was inadequate, which reduced the sample size for the investigated indices — in other words, not all the employees from all areas were subjected to the same occupational tests.

CONCLUSION

The results of the present study suggest that occupational exposure to substances such as heavy metals, metal fumes, carbon monoxide, silica and others represents significant toxicity to metallurgical workers. Independently of the study conclusions, a new study with a larger sample in the same setting is recommended to validate our findings better.

We verified the impact of occupational exposure among metallurgical workers, and emphasize the relevance of promoting regular use of PPE, which is indispensable to enhance the protection against such exposure. Companies in this sector should introduce improvements to ensure the quality of life and of work life of individuals. Measures suggested include: lectures to consent workers about specific exposure to the various work areas; implantation of a system to monitor PPE use and promotion of use by the employer, as e.g., through rewards for compliance; and above all, inclusion of other laboratory tests in PCMSO to help in the early diagnosis of physiological abnormalities among workers. We suggest, for instance, measurement of urinary metabolites — such as hippuric acid (metabolite of toluene), methyl hippuric acid (metabolite of xylene) and δ-aminolevulinic acid (metabolite of lead) — in relationship with the previously described blood tests and the environmental concentration of toxicants found in the work environment for biological monitoring of exposed individuals[9,11,39].

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