ORIGINAL ARTICLE

Respiratory effects of silica inhalation among marble industry workers

Efeitos respiratórios da inalação de sílica em trabalhadores de marmorarias

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ABSTRACT

Introduction: Among the currently disabling occupational diseases 60% are attributed to the respiratory system, with 85% of cases related to silicosis. **Objective:** This study assesses the respiratory effects of occupational silica inhalation among marble industry workers. **Methods:** 21 workers employed in the marble industry in the town if Gurupi-TO between March and May 2012 answered a questionnaire about their respiratory symptoms and smoking habits. All underwent spirometry. For intergroup comparison of smokers, ex-smokers, and nonsmokers the parametric ANOVA test was used and for other analyzes the nonparametric Fisher test, with a significance level of 5% probability. **Results:** The average age of workers was 27±6 years. The prevalence of symptomatic patients was 57%. Comparing the two groups for the presence or absence of symptoms by length of exposure to silica (> or < than 5 years), smoking status, BMI, and spirometric variables obtained, there was no statistical significance. **Conclusions:** no association between the detected symptoms and exposure to silica could be identified. This does not exclude its probable interaction and reinforces the need for more specific studies, such as serial spirometry associated with lung volume analysis or cardiorespiratory fitness tests and exercise tests for a broader assessment targeted at these individuals.

Key words: Silicosis; Workers; Spirometry.

RESUMO

Introdução: *atualmente, entre as doenças ocupacionais incapacitantes, 60% são atribuídas ao sistema respiratório, sendo 85% dos casos relacionados à silicose.* ***Objetivo:*** *este estudo avalia os efeitos respiratórios da inalação ocupacional de sílica em trabalhadores de marmorarias.* ***Métodos:*** *foram incluídos 21 trabalhadores de marmorarias da cidade de Gurupi-TO, no período de março a maio de 2012. Foram submetidos ao questionário de sintomas respiratórios e hábito tabágico. Todos realizaram espirometria. Para comparação intergrupo dos fumantes, ex-fumantes e não fumantes foi usado o teste paramétrico ANOVA e para outras análises o teste não paramétrico Fisher e adotado o nível de significância de 5% de probabilidade.* ***Resultados:*** *a média da idade dos trabalhadores foi de 27 ± 6 anos. A prevalência de indivíduos sintomáticos correspondeu a 57%. Ao comparar os grupos quanto à presença ou não de sintomas, relação ao tempo de exposição à sílica (> ou < 5 anos), hábito tabágico, IMC e às variáveis espirométricas obtidas, verificou-se ausência de significância estatística.* ***Conclusões:*** *não foi possível identificar associação entre os sintomas detectados e a exposição à sílica, o que não exclui sua provável interação e reforça a necessidade de mais estudos específicos, tais como espirometria seriada associada à análise de volumes pulmonares e testes de aptidão cardiorrespiratória com ergoespirometria para avaliação mais ampla e direcionada nesses indivíduos.*

Palavras-chave: *Silicose; Trabalhadores; Espirometria.*

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INTRODUCTION

Currently, among all the occupational illnesses that cause disability, 60% are attributed to the respiratory system with professional morbidity twice greater in men than in women. Occupational respiratory diseases reach higher proportion on people 44 years and older and silicosis can be involved in 85% of occupational respiratory diseases.[1]

It is estimated that about six million Brazilians are exposed to dust containing silica, four million in civil construction, 500,000 in mining and prospecting, and over two million in mineral processing industries where the biggest diagnosed cases with silicosis are related to underground mining.[2]

The interaction of silica particles with the respiratory tract leads to macro-phagocytic activation increasing the release of proteases and free radicals and phagocytic capacity.[3]

The constant alveolar macrophage activation with proteases release and peroxidation leads to alveolar lesion, fibroblastic stimulation for collagen deposition, and inflammatory chemotaxis; all of these pathogenic factors lead to pulmonary fibrosis.[3-5]

The need to evaluate the work environment to determine the degree of risk for respiratory problems and, consequently, to develop prevention methods such as the use of workers protective equipment according to their functions is highlighted. In addition, it is necessary to periodically check the worker's health considering relocation if necessary,[6] and establishing a pulmonary rehabilitation program if the disease is already set, improving the functional independence and quality of life of individuals.[7] These measures prevent functional sequelae in the respiratory system and allow the removal of the worker from the work environment, which reduces the risks of disease and its aggravation, and expenses in the public system with healthcare.

OBJECTIVES

To evaluate the respiratory effects of occupational inhalation of silica in marble workshops workers in the municipality of Gurupi-TO.

METHOD

This was a descriptive, analytical, cross-sectional study conducted between March and May of 2012. All marble workshops workers from the town of Gurupi-TO who voluntarily accepted to participate after reading and signing the informed consent were included in the study. The exclusion criteria were: age less than 18 years old; length of service in the field of stone processing less than three months; work absence at the time of data collection; cognitive deficit that precludes the understanding of questionnaires; and refusal to participate in the study.

Workers from five marble workshops were sampled and classified as asymptomatic and respiratory symptomatic[8], and according to smoking habits[9] such as:

- **asymptomatic:** workers without cough, phlegm, wheezing only upon airway infection and shortness of breath only while flat rushed walking or on inclined terrain, i.e. from 1 to 2 degrees[10];
- **respiratory symptomatic:** those who do not fulfill the criteria for respiratory asymptomatic.

The workers were classified according to smoking habits as: smokers, nonsmokers, and ex-smokers as someone who: consumed cigarettes or any product derived from tobacco regularly or occasionally, with an active habit at the time of the study; never smoked; and reported smoking and quitting, respectively. This classification was carried out according to information provided by the volunteers.

The study was submitted to the Committee of Ethics in Research involving Humans from the Gurupi University Center (UNIRG) and approved under protocol 0201/2011.

Initially, the volunteers underwent anthropometric evaluations obtained in accordance with the procedures proposed by Lohman et al.[11]. Height was measured (centimeters-cm) when positioned in orthostatic position with feet together, arms outstretched along the body, and the front of the measuring tape brand SANNY®, model STANDARD, accuracy of 0.1 cm, positioned on the wall. Body mass was measured in a digital scale Filizola® brand (Filizola Industry S/A., Brazil), with a capacity from 0 to 150 kg/100 g and duly calibrated. The body mass index (BMI) was obtained from the quotient body mass /stature and classified as[12]: normal (18.5 -24.9 kg/m^2), overweight (25.0 -29.9 kg/m^2), and general obesity (> 30.0 kg/m^2).

Subsequently, the workers responded to questionnaires about personal data, function performed, time working in stone processing business, and types of raw material; and for the identification of respiratory symptoms, factors of occupational exposure and frequency of smoking based on the default

structure of the respiratory symptoms questionnaire from the British Medical Research Council – MRC 1976 Respiratory Questionnaire[13] translated into Portuguese by the staff of the Pulmonology Laboratory from Fundacentro.[14]

This questionnaire has questions regarding smoking and cigarette consumption expressing this consumption by multiplying the total number of years of smoking by the number of packs smoked per day.[15]

The questionnaires were applied through an interview with personal contact by a properly trained examiner who read and clarified all questions.

Spirometry was performed by a skilled professional. The spirometric measures evaluated were: forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and average forced expiratory flow from 25-75% of FVC (FEF25-75%) and the Tiffeneau index (TI) = FEV1/FVC using a Neurosoft® brand spirometer, model spiro-spectrum. Spirometry was performed with the worker in a sitting position using a nasal clip. After the explanations, the graphic records began following the recommendations advocated by the American Thoracic Society (ATS)[16] and by Pereira (2002)[17]. The respiratory maneuver was performed three times to obtain the highest of the values.[18]

The volume versus time curve allowed the calculation of the forced vital capacity (FVC); the forced expiratory volume in the 1st second (FEV1) was determined by the method of retrograde extrapolation. The expiratory flow was set between 25 and 75% of the FVC (FEF25-75) and the percentage FEV1/FVC ratio (Tiffeneau index – TI). The accepted FVC and FEV1 were the best values from each worker, even if from different curves. The FEF 25-75 was derived from the curve with the best sum between FEV1 and FVC.[17]

The spirometry data were interpreted by a Pneumologist physiotherapist, expressed in percentages, and compared with reference values intended for the Brazilian population.[17]

Data were analyzed by the BioEstat version 5.0 software adopting the significance level of 5%. Averages and standard deviation were used (age, BMI, exposure time, and spirometry indexes) for the descriptive analysis of variables. The ANOVA test was used for the intergroup comparison of smokers, ex-smokers, and non-smokers. The nonparametric exact Fisher test was used for the other analyses from two independent samples.

RESULTS

The municipality of Gurupi-TO has six marble workshops and only one did not participate in the research. Initially, 21 workers who met the inclusion criteria were evaluated and remained until the end of the study. The average age was 27 ± 6 years old, with prevalence ranging from 26 to 30 years old (47.6%). The male gender was absolute (100%). The highest percentage was concentrated on individuals exposed to silica for more than five years (62%), individuals who have never smoked (47.7%), with normal BMI (52.4%), and in the job as a finishing art processor (52.4%) (Table 1).

Table 1 - Distribution of marble workshops workers according to sex, age, time of exposure, smoking habits, BMI, and job function (n = 21)

	N	%	Average (± sd)
Sex			
Male	21	100	
Age range (years)			
18-25	8	38	
26-30	10	47.6	
31-35	1	4.8	27 (± 6)
36-40	0	0	
41-45	2	9.6	
Time of exposure			
< 5 years	8	38	23 (± 16)- months
>5 years	13	62	98 (± 77)- months
Smoking habits			
Smoker	5	23.8	
Non-smoker	10	47.7	
Ex-smoker	6	28.5	
BMI			
Normal	11	52.4	22 (± 2.1)
Overweight	10	47.6	28.3 (± 2.5)
Job function			
Finishing art processor	11	52.4	
Buffer	5	23.8	
Sawyer	3	14.3	
Production aid	2	9.5	

The respiratory symptoms were characterized by cough, dyspnea, and wheezing. The prevalence of symptomatic individuals accounted for 57% (Table 2).

After application of the smoking habit questionnaire, a low prevalence of smokers was observed with an average of years/pack of 7 ± 6. The comparison

analysis between smoking and spirometry variables from smokers, ex-smokers, and non-smokers showed no statistical significance (Table 3).

Table 2 - Symptoms in marble workshops workers (n = 21)

	N	%
Cough	4	19
Expectoration	0	0
Dyspnea (grade 3 to 5)	4	19
Wheeze	4	19
Total who symptoms	12	57
Total who did not refer symptoms	9	43

Table 3 - Spirometry analysis of variables in groups of smokers, ex-smokers, and non-smokers

	FVC	FEV1	FEV 25-75%	Tiffeneau Index
F	FEV1	FEV 25-75%	Tiffeneau Index	0.88 ± 0.06
EF	0.91 ± 0.08	0.94 ± 0.06	0.94 ± 0.08	0.97 ± 0.02
NF	0.96 ± 0.14	1.00 ± 0.17	1.01 ± 0.31	0.88 ± 0.09

FVC= Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; FEV 25%-75% = Average forced expiratory flow from 25-75% of FVC; Tiffeneau Index = FEV1/FVC ratio; F = smokers; EF = ex-smokers; NF = no-smokers.

The association between spirometry variables and respiratory symptoms showed no statistical significance (p > 0.05) (Tables 4 and 5).

Table 4 - Spirometry analysis of variables in respiratory symptomatic and asymptomatic individuals

	A	S	p
FVC	S	p	0.9297
FEV1	0.99 ± 0.17	1.03 ± 0.12	0.2111
FEV 25%-75%	1.00 ± 0.25	1.00 ± 0.15	0.9931
Tiffeneau Index	0.87 ± 0.07	0.91 ± 0.04	0.2692

FVC= Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; FEV 25%-75% = Average forced expiratory flow from 25-75% of FVC; Tiffeneau Index = FEV1/FVC ratio; A= asymptomatic; S= symptomatic; p=significance level.

Table 5 - Spirometry analysis of variables comparing the asymptomatic and symptomatic group

	FVC			FEV1			FEV 25%-75%			Tiffeneau Index		
	S	N	p	S	N	p	S	N	p	S	N	p
A	3	14	1	2	15	1	1	16	1	2	15	1
SI	0	4		0	4		0	4		0	4	

FVC= Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; FEV 25%-75% = Average forced expiratory flow from 25-75% of FVC; Tiffeneau Index = FEV1/FVC ratio; p=significance level; A= asymptomatic; SI= symptomatic; S=Yes; N= No.

The association between spirometry variables and BMI showed no statistical significance (p > 0.05) (Table 6).

Table 6 - Spirometry analysis of variables in individuals with normal weight and overweight

	PN	SP	P
FVC	0.95 ± 0.15	0.95 ± 0.18	0.5894
FEV1	1.01 ± 0.09	0.97 ± 0.22	0.5835
FEV 25%-75%	1.02 ± 0.17	0.97 ± 0.30	0.6398
Tiffeneau Index	0.88 ± 0.05	0.88 ± 0.08	0.8911

FVC= Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; FEV 25%-75% = Average forced expiratory flow from 25-75% of FVC; Tiffeneau Index = FEV1/FVC ratio; PN= normal weight; SP= overweight; p=significance level.

The association between spirometry indexes and the time of exposure to silica showed no significance (p = 0.05) (Table 7).

Table 7 - Spirometry analysis of variables in the groups of individuals with exposure time to silica dust < 5 and > 5 years

	< 5 years	> 5 years	p
FVC	> 5 years	p	0.1316
FEV1	1.06 ± 0.21	0.95 ± 0.12	0.1226
FEV 25%-75%	1.07 ± 0.24	0.96 ± 0.26	0.3247
Tiffeneau Index	0.89 ± 0.05	0.87 ± 0.07	0.5698

FVC= Forced vital capacity; FEV1 = Forced expiratory volume in 1 second; FEV 25%-75% = Average forced expiratory flow from 25-75% of FVC; Tiffeneau Index = FEV1/FVC ratio; < 5 years = less than 5 years exposure; > 5 years = more than 5 years exposure; p=significance level.

DISCUSSION

The evaluated population was predominantly composed of young individuals; with an average age of 27 ± 6 years and exclusively masculine justified by the physical demands of the job. This age range may have contributed to the results found in the spirometry evaluations. In research conducted with marble workshops workers, the evaluated spirometry indexes FVC, FEV1, FEF25-75%, and FEV1/FVC ratios correlated with the variables of exposure time, smoking, age, and respiratory symptoms in individuals under the age of 45 years and over 45 years of age, being observed that the higher the age, the lower the spirometry indexes[18], which contributes to assign the normal spirometry findings to the age in this study.

Non-smoking workers (47.7%) were prevalent over smokers (23.8%). We infer that this result reflects public policies discouraging smoking.[9, 19]

Similar data were reported in a study with marble workshops workers in the city of Cuiabá – MT. Out of 84 evaluated volunteers, 34 (40.5%) reported smoking and 41 (48.8%) reported not smoking.[8]

No significant difference was found in the comparative analysis of spirometry variables between groups of smokers, ex-smokers, and non-smokers. It is believed that this was a function of the young profile in the evaluated population and low average of cigarette consumption expressed in years/pack.

However, results concerning the spirometric analysis conducted in 70 lapidaries of semi-precious stones exposed to silica demonstrated the FEV1 as 98.93% average in the group with current or previous history of smoking, close to the group who never smoked, 98.41%[20], which underscores the hypothesis that the occupational risk factor is as important as the smoking habit.

The highest percentage of these workers reported more than five years of exposure to dust generated during processing stones because most of the marble workshops in the city are companies operating for a long time but without spirometric changes.

According to Algranti et al.[25], the average time of exposure to silica found in the population was relatively low, as 70.5 (± 71.2) months, i.e. around six years. This exposure time would be sufficient to develop the acute form of silicosis that is considered a rare clinical condition. The development time of chronic silicosis is more than 10 years of exposure.[25]

Ferreira et al.[20] evaluated 70 lapidaries and observed altered spirometry values in workers with average time of exposure to silica of nine years in which the values were higher in the group with normal lung function, which exhibited an average of 6.8 years under the same exposure. Similarly, Bon[22] showed a tendency to reduced FEV1/FVC (13.9% of those evaluated) when evaluating 261 workers from 27 marble workshops in the city of São Paulo.

The most prevalent time obtained in the current study (> 5 years, but less than 10 years of exposure) may have contributed to the lack of statistical significance in the association between spirometry changes and exposure time.

Similarly, in a study conducted with 56 marble workshops workers in the city of Goiânia-GO, no statistically significant difference was observed between spirometry indexes and time of exposure to silica dust ($p > 0.05$).[18]

The frequency of isolated respiratory symptoms found in this study was low (19%), however, when considering the sum of symptoms (cough, dyspnea, and wheezing), most reported symptoms (57%).

In another study, conducted with 457 workers exposed to silica dust, 37.2% of the individuals showed expectoration, 30.5% cough, 17.6% wheezing, 11% dyspnea, and 8.2% hemoptysis .[21] Bon[22] evaluated 27 marble workshops in the city of São Paulo, totaling 267 workers, and detected that 48 (18 %) exhibited wheezing with dyspnea and 5 (1.9%) reported grade 3 dyspnea. Although no statistical correlation with spirometry results was observed, the respiratory symptoms proved that silica is a predisposing factor for the development of respiratory diseases.

In this study spirometry changes did not stand out when individuals with normal weight and overweight were compared. Similar data were verified in 96 adults from both genders divided into groups (not obese and obesity grade I and II) in which no significant difference was observed between the spirometric values of FVC, FEV1 and FEF25-75% from the normal weight and obesity degree I and II groups[23]. Although there are reports of lung function abnormality linked to obesity, the magnitude of these changes shows great variation without association with BMI.[24]

The lack of significant spirometry findings, even with the presence of respiratory symptoms and more than five years of exposure to silica, could be attributed to the fact that the spirometry exam is not considered highly sensitive to detect early changes of respiratory impairment.[25] Pulmonary function tests may be normal in the early stages of silicosis, however, a restrictive and/or obstructive pattern can be observed with the disease progression.[26,27] This can be confirmed when individuals with radiological exams indicative of silicosis but with normal spirometry values are found.[21]

According to Pivetta and Botelho,[8] the best way to prove the deleterious effects of occupational exposure through spirometry would be to analyze the FEV1 longitudinal behavior individually for each worker over time.

The limitations of this study such as the lack of serial spirometry associated to the analysis of lung volumes and tests of cardiorespiratory fitness with ergospirometry tests may have influenced the finding of no association between detected symptoms and exposure to silica.

CONCLUSIONS

No association was observed between respiratory symptoms and inhalation of silica by workers of

marble workshops in this study. Further studies with more specific tests to evaluate the exposure to silica dust and with larger sample size are suggested in association with radiological assessments for improved comparative outcomes.

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