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RELATION OF EXPOSURE TO COAL DUST, CRYSTALLINE SILICA AND PNEUMOCONIOSIS IN WORKERS OF UNDERGROUND COALMINES, CUNDINAMARCA, 2014.

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ABSTRACT

Objective: To determine the level of risk of exposure to breathable coal dust and crystalline silica and prevalence of pneumoconiosis in workers in underground mines of the department of Cundinamarca.

Methods: A cross-sectional study in groups of similar exposure (GSE) in selected mines, the sample size was comprised of 11 companies and 215 workers where environmental sampling was performed to measure levels of coal dust and crystalline silica.

Results: The average age of the evaluated group was 46±9,5 years with predominance in the age group of 40-49 years male, a statistically significant association with coal dust (p = 0.050) was found. No significant association with crystalline silica (p = 0.537) was found. The multivariate logistic regression model showed that variables together explain the appearance of pneumoconiosis in miners tunnel were small business size (OR = 2,67, IC 95%:1.07, 6.66, p = 0.04) risk level scale low carbon (OR=10.4, IC 95%:1.50, 71.41, p = 0, 02) age greater than or equal to 30 years (OR = 7,186, IC 95%:2.98, 17.29,p = 0.001) and smoking for more than one year (OR = 4,437, IC 95%:2.06, 9.55,p = 0.001)

Conclusion:Medium level risk of exposure to coal is related with prevalence of pneumoconiosis and additional factors such as medium company size, experience equal or larger than 30 years, and tobacco use for more than one year for workers of underground mines in Cundinamarca. No significant association was found for crystalline silica.

KEYWORDS Occupational exposure, Pneumoconiosis, Occupational hazards

INTRODUCTION

Worldwide, respiratory diseases, originating from exposure to mineral dust present in the work environment, particularly mining, is a growing problem[1,2]. The productive and extractive processes, combined with the conditions in which workers perform these activities, is conducive to the clinical picture associated with occupational factors[3]. Among these type of pathologies is pneumoconiosis, classified as a group of pulmonary diseases caused by inhalation and accumulation in the lungs of inorganic dusts or minerals[4,5], such as silica, crisotile asbestos, coal dust and talcum. Colombia, as a country with a mining tradition[6] is facing these occupational hazards directly[7,8]; However, currently there are only estimates of workers exposed by economic activity and no official statistics regarding dust levels in underground mining environments that allow for implementation of policies for prevention of diseases associated to mining exploitation and that lead to diminishing the incidence or prevalence of pneumoconiosis[9,10,11]. On the other hand, in similar studies performed in Turkey for a population of an underground mine, up to 30g of total dust was found in the lungs of some individuals, with an accumulation rate of 0,4 to 1.7g of dust retained per year[12,13]. Additionally, factors that determine the harmfulness of dust in the ear are in essence the composition, concentration, particle size, exposure time and the individual's susceptibility[14]. Likewise, in studies performed in China between the years of 2001 and 2011, it was concluded that the prevalence of pneumoconiosis amongst coal workers was 6,02% and the combined rate of patients with tuberculosis was 10,82% compared to the United Kingdom (0,8% between 1998 – 2000) and the US (3,2% in 2000)[15].

On the other hand, the Atlanta Center for Disease Control and Prevention (CDC), the National Institute for Occupational Safety and Health (NIOSH), establish recommendations for the recommended levels of exposure (REL-Recommended Exposure Limits) for a tolerance level value (TLV) of 10 hours, for breathable coal dust in mines is 1 mg/m^3[3,16], quantified with personal measuring equipment for samples in coal mines (CP-SU-Coal Dust Personal Sampler Unit) as defined by norm 30 CFR 74.2. (Code of Federal Regulations US). The REL is equivalent to 0,9 mg/m3 measured as per the definition of breathable coal dust from ISO/CEN/ACGIH (International Standards Organization, American Conference of Industrial Hygienists). The REL is applied for breathable coal dust in coal mines and other trades. NIOSH recommends different REL's for crystalline silica[17].

In Colombia, the Mining and Quarries Sector showsoccupational accidents of 11,799 workers in 2010, 19.987 in 2011 and as of March 2012 shows an indicator of 6.687 workers[18,19]. It is a need of the country reflected through the exposed populations, records of accident rates, macro economical records, government fragility in departments and population vulnerability, evidenced in the effects on health and lag in the quality of life in relation to population with other economic activities in the country[20,21,22,23]. Taking these facts into account, it is understood that controlling exposure to inorganic breathable dust, worker's education and information to entrepreneurs is a determining factor in controlling these diseases, and why this study characterized exposure to coal dust and crystalline silica in workers of underground mines in order to estimate the level of risk and its relation to the prevalence of pneumoconiosis in workers of underground mined.

MATERIALS AND METHODS

A cross-sectional study[24] was performed in similar exposure groups (GES) by trade in each of the selected mines, affiliated to ARL POSITIVA, located in the department of Cundinamarca, (Tausa, Sutatausa, Lenguazaque, Cucunubá and Guacheta). The selection criteria included: inclusion criteria: workers that voluntarily decided to participate in the study were selected, with work experience in the mining sector greater or equal to 10 years and that were currently working at the time of data collection. Exclusion criteria included a diagnosis of tuberculosis and presence of active or currently treated respiratory disease. ARL Positiva provided lists of their companies (161) and members (5.711) in the department of Cundinamarca, the sample size was composed of 11 companies and 215 workers, and an environmental sampling was performed in order to measure the levels of coal dust per individual. The sample was statistically stratified, with a random proportional assignment and by bi-stage conglomerates: stratifies by municipality and conglomerate by company (Primary Sample Unit) and worker (Secondary Sample Unit)[25 ,26].

Companies were classified according to their size by quantity of workers in the following manner: large, more than 100 workers, medium, between 51 and 99 workers and small, between 1 and 50. The following study variables were defined: as a dependent variable, pneumoconiosis, and as main independent variable, exposure to coal dust (mainly made up of bituminous tar) and crystalline silica. The confusion variables were: worker's experience within the mining sector and current time at the current job, both in number of years. Two categories were established for the study variables. In the first category, the socio-demographical differences were defined and the in the second category, the occupational variables. Subsequently, the test to evaluate the instruments was performed in order to later make the necessary adjustments. The quality of the recorded data was insured by digitation control of the data base in 100% of the survey questionnaires.

PROCEDURE AND USE OF INSTRUMENTS.

Before initiating the field work, a hygienist established the GES' (Similar exposure groups) according to work environment characteristics; personal samples were obtained in simple random manner in order to select the workers therein defined. The coal and crystalline silica sampling was made by calibrated aspiration pumps, using PVC filters. The air sample was obtained with a volume of 1.2 to 2 L/min using a 2 or 3-body cassette with a polyvinyl chloride diaphragm. For the breathable dust establishment process, a cyclone coupled with the cassette was placed, adjusting the volume to 1.7L/min as well as a sampling of critical points in the selected mines to determine the air concentration of the fraction of breathable dust and silica dust. A gravimetrical analysis was then performed using the 0600 validated method from NIOSH (National Institute for Occupational Safety and Health of the US)[27], that included the collection of the sample in PVC filters, using a nylon cyclone with a 10mm orifice and gravimetrical analysis. The detection limit was 0.03mg. For silica, an infrared absorption spectrometer was used which determined the fraction contained in the sample collected in the filters; this determination was made following the 7602 NIOSH method[28,29].

Additionally, the allowed limit established by the American Conference of Governmental Industrial Hygienists (ACGIH) was used, adjusted for Colombia for an 8-hour workday, 6 days a week, of 0.019625 mg/m^{3}for crystalline silica, defining five levels of risk: low (relation of obtained concentration / adjusted TLV lower than 0.5), medium (between 0.5 and 1), high (between 1 and 2), severe (greater than 2 but with a relation lower than 5), and critical (larger than 5) were statistically significant differences were found (p<0.000) in the risk levels per department. On the other hand the adjusted limit value adjusted for 8-hour workdays, 6 days a week was 0.7065 mg/m^3 forcoal dust (bituminous tar). Four levels of risk were established: low (relation of obtained concentration / adjusted TLV lower than 0.5), medium (between 0.5 and 1), medium (relation of 0.5 to 1), high (greater than 1 but less than 5), and severe (greater than 5), were statistically significant differences were found (p <0.0001) for the risk levels per department. These adjusted TLV's were obtained using the Brief & Scala pharmacokinetic method[30].

STATISTICAL ANALYSIS

Percentage and absolute frequency distributions were used as the qualitative type variables for the description; quantitative variables were calculated with central trend measurements, variability and dispersion measurements with their corresponding variation coefficients in order to measure the homogeneity of the data[31].

The association between categories of risk levels for coal dust and pneumoconiosis and the association between crystalline silica and pneumoconiosis was determined using the Chi-squared Pearson association test or the Fisher exact test (expected values <5) with the OR and corresponding trust level of 95%; to evaluate the numerical coal and crystalline silica levels the T Student test was performed for independent groups. The homogenous and heterogeneous variances were evaluated using the Levene test.

In cases of non-compliance of the normality assumptions in the Shapiro Wilk test, the non-parametrical Mann-Whitney U test was performed as well as the Kruskal-Wallis test. To determine the association between the risk level and pneumoconiosis a multivariate analysis was performed (for coal dust, the variables were controlled using an unconditional logistics regression model). Statistical tests evaluated a significance level of 5%(<0,05)[32,33,34,35,36].

The scientific technical and ethical endorsement was obtained from the Committees of the National Health Institute and the Rosario University, the study was classified as minimum risk according to Resolution 8430 of 1993 by the Ministry of Health.

RESULTS

The study sample included 215 workers from underground mines and 11 companies from the department of Cundinamarca. The distribution of the sample per municipality was: Guacheta with 83 (38,6%) workers, Sutatausa with 66 (30,7%), Tausa with 15 (7,0%), Cucunuba with 26 (12,1%) and Lenguazaque 25 (11,6%); additionally, companies are classified as (n=3) large size, (n=5) medium size y (n=3) small size. The average age of the evaluated group was 46±9,5 years, with a range of 23,76 years, and a preponderance of the age group of 40 to 49 years was found, of male gender, economic strata II and incomplete primary education level. (Table 1)

Additionally, the type of job of the total number of workers was categorized as follows:

pickers 108 (50%), enhancers 29 (13,5%), pit supervisors 21 (9,8%), development miner 14 (6,5%), unloaders 13 (6%), coachmen 13 (6%), hoistmen 11 (5,1%), supplies 5 (2,3) y locomotive operator 1 (0,5%).

Table 1. Frequency of the socio demographic variables of underground mine workers in the department of Cundinamarca, 2014.

Socio demographic Variables	Description	Frequency	Percentage
Age Groups	20-29,9	10	4,70
	30-39,9	49	22,80
	40-49,9	73	34,00
	50-59,9	70	32,60
	>=60	13	6,00
	Total	215	100,00

Gender	Male	209	97,20
	Female	6	2,80
	Total	215	100,00
Socio-economical Strata	1	8	3,70
	2	125	58,10
	3	68	31,60
	4	12	5,60
	5	2	0,90
	Total	215	100,00
Marital Status	Single	26	12,10
	Married	81	37,70
	Common Law	93	43,30
	Divorced	12	5,60
	Widower	3	1,40
	Total	215	100,00
Educational Level	None	4	1,90
	Incomplete Primary	83	38,60
	Complete Primary	79	36,70
	Incomplete High school	29	13,50
	Complete High school	17	7,90
	Incomplete Technical	0	0,00
	Complete Technical	1	0,50
	Complete University	2	0,90
	Total	215	100,00

The relation between the coal dust concentration and pneumoconiosis was significant(p=0,050)and there was no association between crystalline silica and pneumoconiosis (p = 0,537).

It was found that 44,4% (80) of the workers from the sample had presence of pneumoconiosis according to the OIT criteria. From the workers diagnosed with pneumoconiosis, 42,6% (60) were found at high risk and 55,6% (100) remaining from the sample had no presence of pneumoconiosis although out of those, 57,4% (81) were found at high risk from exposure to coal dust.

Table 2. Measures describing concentration and risk of coal dust and crystalline silica for pneumoconiosis in workers of underground mines in the department of Cundinamarca, 2014.

Pneumoconiosis OIT Concentration		COAL		SILICA	
		Risk	Concentration	Risk	
Yes	Media	3,1728	4,5326	0,0824	4,1191
	Tip. Dev.	2,12167	3,03095	0,08435	4,21739
	Median	3,2847	4,6924	0,0567	2,8335
	Minimum	0,16	0,22	0,01	0,5
	Maximum	8,61	12,3	0,51	25,69
	N	80	80	80	80
No	Media	2,9597	4,2282	0,1054	5,2678
	Tip. Dev.	2,11213	3,01733	0,13089	6,54469
	Median	2,8565	4,0807	0,0615	3,075
	Minimum	0,14	0,19	0,01	0,5
	Maximum	8,61	12,3	0,74	37,18
	N	100	100	100	100
Total	Media	3,0544	4,3635	0,0951	4,7572
	Tip. Dev.	2,11312	3,01874	0,1129	5,64511
	Median	3,2847	4,6924	0,0615	3,075
	Minimum	0,14	0,19	0,01	0,5
	Maximum	8,61	12,3	0,74	37,18
	N	180	180	180	180

According to the tolerance level value of coal dust adjusted from TLV – TWA 0,7065 mg/m^{3}a result of 3,054 mg/m^{3}was obtained for exposure to the underground miners. As for crystalline silica (quartz and cristobalite) the tolerance level value adjusted according to the ACGIH for 2006 is0,0196 mg/m^3, for coal dust and 44,8% (64) for crystalline silica at high risk. A sever risk for coal dust was found at 3,3% (4) of the workers and a 2,2 (4) for crystalline silica.

According to external factors found and classified in the study, it was found that there is significant association to the size of the company (p=0,041), as well as for the position (p=0,014), however there is no statistically representative association for the type of extraction (p=0,325). The size of the company for medium sized company had an association of 48,7% (55), and 56% (14) associated to the manual extraction of coal and 54,6% (59) with the position of the rockbreaker. (Table 3)

TABLE 3. Relation between risk variables, company, extraction and position with prevalence of pneumoconiosis according to OIT criteria..

Risk variables, company, extraction and position		Classification Frequency	Prevalence of Pneumoconiosis According to OIT Criteria	
			Percentage	
Coal (Level)	Low		4	26,7
	Medium		10	76,9
	High		60	42,6
	Severe		6	54,5
	Total		80	44,4
Silica(Level)	Medium		12	50
	High		64	44,8
	Severe		4	30,8
	Critical		0	0
	Total		80	44,4
Company (Size)	Large		20	43,5
	Medium		55	48,7
	Small		16	28,6
Extraction (Type)	Manual		14	56
	Machined		50	39,7
	Machined and manual		27	42,2

Position(Type)	Coachman	3	23,1
	Unloader	5	38,5
	Development	5	35,7
	Hoistman	4	36,4
	Rockbreaker	59	54,6
	Enhancer	5	17,2
	Pit Supervisor	7	33,3

Taking into account the results of the final multivariate analysis an association was established between pneumoconiosis and the medium level coal dust concentration for the variables: medium company size, medium coal risk scale, experience of more or equal to 30 years and tobacco habit for more than 1 year. (Table 4)

TABLE 4. Multivariate association logistic regression model (experience in position, size of company, risk scale and tobacco use).

Variables			B	Standard Error	Significance Level Inferior	OR Superior	I.C. 95% for (OR)	
1st step	Company Size	Small*	-	-	0,05	1,000	-	-
		Medium (1)	-0,08	0,61	0,9	0,928	0,28	3,078
		Large (2)	0,983	0,47	0,04	2,671	1,071	6,661
	Coal Scale	Low*	-	-	0,08	1,000	-	-
		Medium (1)	2,337	0,99	0,02	10,352	1,501	71,417
		High (2)	0,394	0,69	0,57	1,483	0,386	5,693
		Severe (3)	0,507	0,72	0,48	1,66	0,405	6,805
	Experience	< 25 years*	-	-	0	1,000	-	-
		25-29.9 years	1,927	0,49	0	6,871	2,633	17,927
		>= 30 years	1,972	0,45	0	7,186	2,985	17,299
	Tobacco use for more than one year	Yes Answers	1,49	0,39	0	4,437	2,061	9,555
		No Answers *	-	-	-	1,000	-	-
		Constant	-2,76	0,75	0	0,063	-	-

**Comparison variables*

The percentage of prediction for the multivariate model was 73,00% with an adjustment of the logistic model to explain the presence of Pneumoconiosis with the included variables. The model has a specificity of 67,50% and a sensitivity of 76,00%.

DISCUSSION

For the year 2000, according to a study from the OMS of global charge of non-malignant respiratory disease at a global level, it was calculated that pneumoconiosis derived from exposure to silica, asbestos and coal dust caused 30,000 deaths and 1.240.000 years of healthy life lost (AVAD), with anthracosis being the disease that most contributed to total deaths. Likewise, it was established in 2004 that at a global level 318.000 people die due to chronic obstructive pulmonary disease (EPOC), 100.750 due to cancer of the tracheae, bronchia or lung and 9.000 for silicosis associated with occupational agents[37].

Additionally, in studies carried out by coal mines in Turkey between the years of 1978 and 2006, similar results to those of this study were found, were concentrations of dust exceed 3,55 mg/m^{3}in various tasks performed[38]; on the other hand, studies performed in South Africa found high levels of exposure to of 3,417 ± 0,862 mg/m^{3}and levels of exposure to breathable silica dust of 0,179 ± 0,388 mg/m^3[39].

When comparing the study with the one performed in the underground coal mines in Amaga - Colombia[40], similar results were found in relation to a high prevalence o pneumoconiosis associated to position and experience in that position; it was also evidence that 82% are at risk of suffering from this disease with these factors, were it is association with external factors defined by this study, such as those determined in the logistic regression model, were the "pneumoconiosis" dependent variable was better explained by "experience in the position (greater or equal to 30 years) and tobacco use for more than one year", the small company type and low carbon risk; once the effect of the other variables in the model is controlled.

The data obtained corroborated the fact that onset or presence of the disease in underground coalmines, is influenced by multiple factors that condition its development, perpetuation and outcome. These results could indirectly suggest that the occupational health and environmental programs of the company are weak or inexistent, coupled with low coverage and effectiveness of health promotion, prevention and intervention programs for miners in the referenced department.

Determining these variables together with a quick and effective intervention of the controllable risk factors favors interruption of a process that would otherwise have dire results for the individual or organization.

The results obtained in this study agree with the statistics for occupational breathing diseases derived from exposure to mineral dust described by the World Health Organization (OMS) as prevalent diseases in developed countries as well as underdeveloped countries.[41].

It is important to note that biases of information and memory were contemplated, and in order to counter them, standardized surveys were used for workers as well as companies, and to mitigate low recollection, the timing of the question was less than 6 months.

CONCLUSIONS

It was found that mining companies that make up the study sample have high levels of crystalline silica and even higher levels of coal dust, given that it represents a critical-severe risk for individuals working under established occupational conditions. The overexposure of individuals to such high levels in proportion of breathable coal dust (Bituminous tar) is associated with the probability of contracting pneumoconiosis; and other factors that significantly impact such as: experience larger or equal to 30 years, medium sized companies and tobacco use of more than one year. On the other hand there was no statistically significant association with crystalline silica in the different risk levels associated with the prevalence of pneumoconiosis in the study.

RECOMMENDATION

Control measures to mitigate dispersion of dust in work areas must be implemented. These measures may be implemented taking into account the area or work section. For underground processes it is important to drill with water injection at the seams of the streaks before initiating production work. For external processes there must be a suppression of dust during manipulation, classification and transportation in the area with the use of pressurized water curtains; additionally, periodical measurement of dust concentration and use of adequate personal protection masks according to the NIOSH technical norms, reinforcing the process with adjustment tests of the masks in order to reduce the breathable proportion in those areas where dust suppression is not enough. Even tough

the mean exposure to breathable coal dust and crystalline silica was found to be higher that the established TLV, in order to minimize risk of contracting pneumoconiosis amongst workers, the national levels of admissible dust should be formalized so that they are less than those referenced by international entities.

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The Research group declares not to have any economic or personal conflict of interest that influence their judgment or action or that generate biases while elaborating this article.

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