CORRELATIONS BETWEEN RADIOLOGY, RESPIRATORY SYMPTOMS AND SPIROMETRY IN ACTIVE UNDERGROUND COAL MINERS IN BRAZIL[a]

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INTRODUCTION

In Santa Catarina's coal district, with around 200,000 inhabitants, there are about 2,000 cases of pneumoconiosis, most of which are from underground coal mining.

It is suspected that the coal mining industry, the main local economic activity, is responsible not only for pneumoconiosis but also for airway chronic irritation-resulting pathologies. Pneumoconiosis is caused directly by occupational dust exposure and the other related pathologies are caused by a number of factors, especially dust exposure,[12] cigarette smoking and occupational and environmental exposure to SO_2,[14] which is high due to the existence of underground diesel exhaust machines and of large open coal depots and rejects. Brazilian coal is rich in sulphur.

Some previous papers related to coalworkers pneumoconiosis (CWP) in Brazil have already been published. They focus on clinical and radiological aspects of the cases[15] and the occurrence of progressive massive fibrosis.[16] We lack information, i.e., epidemiological data which address questions about the occurrence, not only of pneumoconiosis, but also about the prevalence of respiratory symptoms and functional impairment of the exposed population.

Dust exposure conditions in Brazilian coal mining are different from those where classical works on CWP were performed. The Brazilian coal has plenty of ashes, i.e.; just 60% of mined material is coal. Many environmental measurements show high quartz concentrations, often above 10%[17] which makes us suppose that the CWP in Brazilian mines has a distinct clinical and evolutive behavior from the classical CWP. Probably the same happens in relation to respiratory symptoms and lung function impairment.

This is the first prospective epidemiological study about the respiratory compromise in active Brazilian underground coalworkers.

METHODS

During 1984, six underground mines in Santa Catarina's coal district were investigated. They employed 2,134 miners, which corresponded to a third of the underground miners in the region. One of the mines was manual, 3 were semimechanized and 2 were mechanized. A random sample of 50% of the miners (within each job description) was selected from the 6 mines' records. A summary of the sample is presented in Table I. Sickness absence, vacation and refusal were the reasons for the absence of workers. In these cases there was no replacement.

The 956 miners were submitted to a questionnaire on respiratory symptoms adapted from a questionnaire on Chronic Bronchitis (MRC, UK, 1976) by 6 trained professionals, and a spirometry with a dry-wedge spirometer (Vitalograph, Vitalograph Limited, Buckingham, UK).

A minimum of 3 curves were obtained for each miner. For analysis, only spirometries having a maximum difference of 100 ml for the FEV_1 between the 2 best curves were accepted.[1] FEV_1, FVC and the ratio of FEV_1/FVC were calculated. The values were transformed to BTPS.

The companies were responsible for the radiographs, which were considered valid until 1 year before the interview. Each radiograph was read independently by 3 experienced readers, according to the 1980 ILO International Classification.[7] The profusion of small opacities was given by the median of the 3 readings.

The exposure index used was the number of years spent underground (number of years of exposure, NYE) in one or more jobs described individually. Approximately one third of the miners referred having had more than one job. The smoking habits were calculated in pack-years (PY), and the nutritional status by the formula weight/height^2 (Quetelet Index).

The correlations between two variables were analysed through contingency tables. The correlations between NYE, PY and functional respiratory parameters were obtained through loglinear[3] and multiple linear regression models. The correlation of multiple variables and the occurrence of pneumoconiosis was initially analysed through a multiple linear regression model, where the relative importance of the independent variables was deduced. Due to the existence of dichotomous variables a probit regression analysis was also performed[4] to predict the probability of occurrence of the dependent variable (in this case, pneumoconiosis). Throughout this study "p" values were considered significant below the 5% level.

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RESULTS

The mean age of the 956 miners was 30.7 ± 5.7 (21–50). The mean number of years of exposure (NYE) was 5.8 ± 4.5 (0–26).

Only 816 radiographs were obtained from which 108 were considered inappropriate for reading (quality 4). The prevalence of pneumoconiosis was 5.6% (40 cases with profusion 1/0 or above). The NYE of miners with pneumoconiosis was 8.4 ± 4.7. Eighty cases (11.3%) were read as profusion 0/1 and the remaining 588, 0/0.

The presence of respiratory symptoms is presented in Table II. Cough and/or phlegm were only considered positive if they were present for at least 3 months. Breathlessness was considered positive if it occurred at heavy efforts.

Table III shows the lung function tests mean values for 768 miners. The remaining 188 (20%) had their spirometries invalidated because of technical defects. Both groups had a similar mean age and mean height but miners with accepted spirometries, had the mean NYE significantly lower ($p < 0.01$).

The distribution of the observed/predicted FVC and FEV_1 values was similar: 41.3% of the miners presented FEV_1 lower than 80% and 39.8% FVC lower than 80%, while 8.7% presented FEV_1 lower than 60% and 7.5% FVC lower than 60%. Only 9.8% of the miners presented the ratio FEV_1/FVC lower than 70%.

Out of the 956 miners, 580 (60.7%) were smokers, 128 (13.4%) ex-smokers and 248 (25.9%) non-smokers. The

Table I
Sampling of Underground Miners

MINE	METHOD*	Nº OF MINERS	SIZE OF THE SAMPLE	Nº OF MINERS ATTENDING	% ATTENDING
1	SM	191	93	73	78
2	Me	250	128	122	95
3	Me	595	306	260	85
4	SM	598	299	274	92
5	SM	267	135	130	96
6	Ma	233	102	97	95
TOTAL		2134	1063	956	90

* SM = Semi Mechanized
Me = Mechanized
Ma = Manual

Table II
Cough, Phlegm and Breathlessness in Underground Miners

	COUGH (%)	PHLEGM (%)	BREATHLESSNESS (%)
Yes	331 (34,7)	337 (39,5)	291 (30,4)
No	625 (65,3)	619 (60,5)	665 (69,6)
TOTAL	956 (100)	956 (100)	956 (100)

smokers' pack-years mean (PY) was 10.1 ± 8.4 and the ex-smokers' 11.2 ± 9.9.

Table III
Mean Values of Lung Function Tests in 768 Miners

TEST	MEAN ± SD
FEV_1 (1)	3.73 ± 0.64
FVC (1)	4.59 ± 0.73
FEV_1/FVC (%)	81.2 ± 9.00
FEV_1 O/P (%)	95.5 ± 30.30
FVC O/P (%)	102.0 ± 35.00

Table IV shows the isolated correlations between NYE, PY, lung function tests and respiratory symptoms. Both NYE and PY presented a significant correlation with the presence of cough, phlegm and breathlessness. Regarding lung function tests, only a significant negative correlation was found between NYE and FEV_1/FVC.

The influence of smoking and the number of years of exposure were studied in relation to lung function tests in loglinear and multiple linear regression models, the latter with FEV_1, FVC and FEV_1/FVC as dependent variables. The results are presented in Tables V and VI. (The results of the loglinear model which comprises FEV_1, PY, and NYE were omitted for being similar to the results obtained through the model with FVC, PY and NYE).

Loglinear models indicated that in the analysis between NYE, PY and FVC, and NYE, PY and FEV_1, the structure that better explains both relationships contains a significant association between NYE and PY. The iterations between NYE, PY and FEV_1/FVC had low "p" values, thus were not analysed. The multiple linear regression analysis showed that the effect of NYE was more relevant in relation to FEV_1 and FVC hut PY is more relevant in relation to FEV_1/FVC.

Finally, the behavior of respiratory symptoms, functional parameters and NYE and PY were analysed in relation to the presence of pneumoconiosis. In the first analysis a multiple linear regression model was fitted with profusion of small opacities as the dependent variable. The results are shown in Table VII. NYE and breathlessness were significantly associated with the presence of pneumoconiosis. FVC was not considered as an independent variable in the above-mentioned table. PY was neglected due to its minimum contribution in the equation.

The multiple linear regression model is not the most suitable for analyzing variables with dichotomous values such as cough, phlegm and breathlessness. For a better understanding of the relationships we applied the probit regression technique, assuming for the dependent variable (profusion) a dichotomous value (0 = category 0, 1 = category 1 or above). The respiratory symptoms such as cough, phlegm and breathlessness assumed the values 0 = absent and 1 = present). The FVC and FEV_1 are expressed in centiliters. The results are presented in Tables VIII to X.

The probit regression analysis confirms the significance of NYE and breathlessness in relation to the prediction of pneumoconiosis and in addition it shows a significant correlation with FEV_1/FVC (positive) and FEV_1 (negative). The distribution of the predicted values among the subjects shows that there is a good chance of classifying an individual correctly given known variables.

DISCUSSION

The radiological evaluation was affected since the industries were in charge of the examinations. Consequently 140 radiographs were not sent and 108/816 were considered inadequate for classification. The prevalence of 5.6% of pneumoconiosis is not high. However, the mean NYE of cases is very low. The CWP prevalence in underground United States miners in the late 70's was just below 5%, but the mean exposure time was much higher than the 8.4 years here observed.[13]

The quartz concentrations exceeded 10% in more than one third of the samples of respirable dust in the investigated mines. In three fourths of the samples the TLV of quartz was exceeded.[17] These quartz concentrations are likely to affect the estimates of pneumoconiosis prevalence in underground coal mining when compared to countries where there are lower quartz concentrations.[8]

Approximately 1/3 of the miners complained of cough, phlegm and breathlessness. This figure seems to be excessive, nevertheless, there are not comparative data available from a control population. The environmental levels of SO_2 are high in the region due to the existence of large open coal depots.

A third of the miners, having valid lung function tests, presented the FEV_1 and the FVC below 80%. Miners with rejected lung function tests for analysis (20% of the sample) have shown a NYE mean significantly higher than the miners with valid tests. This may probably have underestimated the functional effects resulting from dust exposure. Both NYE and PY correlated significantly with the presence of cough, phlegm and breathlessness.

The analysis of the NYE and PY influence over the functional parameters showed that only NYE associated significantly with the drop in FEV_1/FVC. When the effects of these two factors were analysed in a multiple linear regression model, NYE proved to be more important in relation to the decline in FEV_1 and FVC, while PY proved to be more important in relation to the decline in FEV_1/FVC. This latter is, comparatively, a better isolated test for bron-

Table IV

X^2 Values for Contingency Tables. Number of Years of Exposure (NYE) or Pack Years (PY) and Lung Function Tests of Respiratory Symptoms

	NYE (DF)	PY (DF)
FEV_1	6.02 (4)	2.2 (4)
FVC	1.7 (4)	3.3 (4)
FEV_1/FVC	9.5* (4)	5.5 (4)
COUGH	21.2*** (2)	20.2***(2)
PHLEGM	11.6** (2)	6.15* (2)
BRETHLESSNESS	50.8*** (2)	13.9***(2)

* $p \leq 0.05$
**$p \leq 0.01$
***$p \leq 0.001$
DF = Degrees of Freedom

Table V

Observed Adjusted Values for the Log Linear Model PY.FVC, PY.NYE (Probability = 0.6876)*

		PY				
FVC	NYE	NS	10	10	ES	TOTAL
< 0.60	0 - 5	9(7.3)	8(11.9)	2(2.5)	0(0.5)	19
	5 - 15	2(4.1)	8(4.8)	3(2.3)	1(0.5)	14
	15 -	1(0.5)	1(0.3)	0(0.2)	0(0.0)	1
0.60 - 0.60	0 - 5	42(42.2)	62(61.5)	33(28.7)	1(1.0)	138
	5 - 15	24(23.8)	25(25.1)	23(26.7)	1(1.0)	73
	15 -	3(3.0)	1(1.5)	2(2.6)	0(0.0)	6
> 0.80	0 - 5	136(76.5)	136(132.7)	54(57.9)	5(4.5)	270
	5 - 15	45(43.1)	51(54.1)	57(53.9)	4(4.5)	157
	15 -	5(5.5)	3(3.2)	6(5.2)	0(0.0)	14
T O T A L		206	285	180	12	693

* λ and t values were significant only to 2 levels of FVC and to all levels of the table PY x NYE.

Table VI
Coefficients, Standard Error (SE) and F Value of the Multiple Linear Regressions

DEPENDENT VARIABLE	INDEPENDENT VARIABLES	COEFFICIENT	SE	F
	CONSTANT	368.6514		
FEV_1	NYE	-2.0007	0.5122	15.25*
	PY	-0.4581	0.2671	2.94
	CONSTANT	445.9138		
FVC	NYE	-1.9781	0.5903	11.23*
	PY	-0.2002	0.3078	0.42
	CONSTANT	82.6080		
FEV_1/FVC	PY	-0.1457	0.0399	13.31*
	NYE	-0.0898	0.0766	1.37

*$p < 0.005$

Table VII
Coefficients, Standard Error (SE) and F Value of the Multiple Linear Regression, Dependent Variable: Profusion

	COEFFICIENT	SE	F
Constant	0.2664		
NYE	0.1396	0.0385	13.13*
BREATHLESSNESS	0.1957	0.0723	7.32*
COUGH	0.0807	0.0749	1.16
FEV_1	-0.0003	0.0003	1.10
QUETELET INDEX	0.0640	0.0764	0.70
PHLEGM	0.0417	0.0712	0.34
FEV_1/FVC	0.0013	0.0032	0.16

*$p < 0.005$

Table VIII
Probit Regression Coefficients. Dependent Variable: Profusion (0 or 1)

	COEFFICIENT	SE	T	P
CONSTANT	-9.4601	4.9535	-1.9098	0.0562
NYE	0.0582	0.0183	3.1835	0.0015*
BREATHLESSNESS	0.5627	0.1809	3.1109	0.0019*
FEV_1/FVC	0.1235	0.0595	2.0762	0.0379*
FEV_1	-0.0265	0.0129	-2.0532	0.0401*
FVC	0.0192	0.0105	1.8247	0.0680
QUETELET INDEX	-0.0492	0.0301	-1.6348	0.1021
COUGH	-0.1141	0.1965	-0.5809	0.5614
PHLEGM	0.0374	0.1915	0.1953	0.8452
PY	-0.0007	0.100	-0.0074	0.9407

chial obstruction. The loglinear model showed that the interaction cigarette smoking-years of exposure was significant for the structure of the relationships with FEV_1 and FVC.

Table IX
Change in Probability Evaluated at P = 0.056

	P = 0.056
NYE	0.0066
BREATHLESSNESS	0.0639
FEV_1/FVC	0.0140
FEV_1	-0.0030
FVC	0.0022
QUETELET INDEX	-0.0056
COUGH	-0.0130
PHLEGM	0.0042
PY	-0.0001

The contribution of dust exposure on lung function was at first minimized in the literature, due to the complexity of the analysis of all respiratory hazard factors related to coal mining.[11] Recent and reliable data clarified these points, showing the relationship between dust exposure in coal mines and respiratory symptoms.[5,9] Data analysis on the relationship between dust exposure and cigarette smoking was addressed by Elmes.[2] In British coal industry, cigarette smoking is today the main cause for determining miners' functional deterioration, although both factors have their contribution. A more recent paper on these relationships in British coal workers showed that the combined effect of dust exposure and cigarette smoking appears to be additive, and there are no definite proofs, that smoking is more important than dust exposure.[10]

Although there are no routine dust sampling in Brazilian coal mines that permit us to derive cumulative indices of exposure, it can be supposed that dust exposure hazards in Brazilian coal mines are not comparable to British, American and German findings due to qualitative differences in respirable quartz. In fact, the loglinear analysis indicates an important effect of the association between cigarette smoking and dust exposure on the determination either of FEV_1 or FVC. Since miners with rejected lung function tests presented a mean NYE significantly higher than the analyzed group, the effect of dust exposure on the lung function parameters is likely to be underestimated. We believe that only the longitudinal follow-up of these miners will clear up the confused correlations of these variables.

Table X

Predicted Probabilities (in Intervals of 0.1) by Observed Value (0 or 1)

	PREDICTED									
	0-.09	.1-.19	.2-.29	.3-.39	.4-.49	.5-.59	.6-.69	.7-.79	.8-.89	.9-1.0
OBSERVED										
0	568	78	19	3	0	0	0	0	0	0
1	21	14	2	3	0	0	0	0	0	0

The multiple linear regression model showed that NYE followed by breathlessness are the most significant factors related to pneumoconiosis. Multiple linear regression models are not suitable in the presence of dichotomous variables due to its difficulties in estimating probabilities restricted to the interval 0.1. In addition, the multiple linear regression assumes that the effect of the independent variahles is constant along the whole variation of the predicted dependent variable. The probit regression analysis seems to be more appropriate in these circumstances and yields estimated coefficients which are asymptotically unbiased, efficient and consistent.[4]

The results of the probit analysis were similar to those of the multiple regression analysis including the FEV_1/FVC and FEV_1 as significant variables. This analysis demonstrates that for each year of exposure a 0.6% effect is added to the observed probability of pneumoconiosis (5.6%). Cough, phlegm and smoking had no relation with the presence of pneumoconiosis. In British coal miners, smoking does not affect the risk of developing CWP.

These data indicate a probable excess of respiratory symptoms in Brazilian coal miners. Cough, phlegm and breathlessness were significantly related to both dust exposure and smoking. The association of dust exposure and smoking showed a significant effect in relation to the FEV_1 and FVC. Although the dust exposure effect was underestimated, we are not able to conclude which one of these variables was more responsible for lung function deterioration. The most determinant factor, as far as pneumoconiosis is concerned was the dust exposure; individuals with pneumoconiosis tended to have breathlessness and a low FEV_1. This group of miners will be followed up in 1989.

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