DEVELOPMENT OF PNEUMOCONIOSIS AND OUTSOURCING WORK IN PERUVIAN MINERS

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ABSTRACT

Objetives. The aim of this study is to evaluate the association between the time of outsourced work and the development of pneumoconiosis in Peruvian miners who attended the "Centro Nacional de Salud Ocupacional y Protección al Ambiente para la Salud" between 2008 and 2011. ***Materials and methods.*** Retrospective case-control study. Cases were defined as workers diagnosed of pneumoconiosis under standardized criteria. Outsourced work was defined as the time (in months) of work in a company that does not own the primary mining project. The project owner company was registered in the Mining Companies Directory (Ministerio de Energía y Minas). We used multiple logistic regression with crude and adjusted ORs. ***Results.*** The study comprised 391 cases and 1519 controls. In both groups, most of the study subjects had a level of education lower than complete high school and were born and currently lived in the Peruvian highlands. There was statistically significant association between more frequency of pneumoconiosis and working 10 or more years in an outsourced company (OR: 1.50; 95%CI: 1.05-1.14; p=0.026). Miners with pneumoconiosis were more likely not to have education (OR: 3.07; 95%CI: 1.55–6.08; p=0.001), be currently living at the Peruvian highlands (OR: 1.40; 95%CI: 1.10-1.78; p=0.007) and to have more than 20 years of underground work history (OR: 8.92; 95%CI: 4.53-18.25; p<0.001). ***Conclusions.*** A statistically significant association was found between pneumoconiosis and the time of outsourced work. Not having education, residing in the Peruvian highlands and the time of underground work were associated risk factors.

Key words: Pneumoconiosis; Mining; Outsourced services (source: MeSH NLM).

INTRODUCTION

Mining is considered an important economic sector due to its ability to generate resources for other sectors, such as metallurgy, agriculture, and information technology, and to contribute to the sustainable socioeconomic development of the population, both nationally and internationally [(1)]. According to the World Bank, some of the main benefits of mining investment are the increased tax revenues and export income as well as greater work opportunities and development of infrastructure (especially in rural areas) [(2)]. It is important to point out that Peru is considered one of the world's leading producers of precious metals [(3)].

On the other hand, mining conditions pose a risk to workers due to occupational accidents (869 fatal accidents were recorded in the Peruvian mining industry between the years 2000 and 2014, according to the Ministry of Energy and Mines) [(4)] as well as constant exposure to chemical, biological, ionizing-radiation-related, mechanical, and environmental hazards. Among the latter are the conditions that expose workers to occupational hazards such as heights over 1500 meters, high levels of noise, extreme temperatures,

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inadequate ventilation during underground mining, and exposure to inorganic dust, the latter being the cause of pneumoconiosis [5].

According to the International Labor Organization (ILO), pneumoconiosis is defined as accumulation of dust in the lungs and the secondary inflammatory reaction to this condition, where "dust" refers to an aerosol consisting of inanimate solid particles. It may or may not cause respiratory symptoms. From a pathophysiological standpoint, pneumoconiosis can be subdivided into collagenous and noncollagenous forms depending on whether the type of inorganic agent is fibrogenic or not, respectively. This disease is chronic and progressive, and the development of the collagenous forms occurs during long periods, from 10 to 15 years, with varying degrees of pulmonary fibrosis. There are also rapidly progressive forms (development of a disease within months or less than 2 years) due to massive exposure within a short period to certain substances such as silica [6].

The main risk factors of pneumoconiosis are age, duration, and magnitude of exposure to mine dust (e.g., seniority, type of mine [open pit or underground], high concentrations of free silica, and other agents in mine dust, job inside the mine) [7-11].

Outsourcing is common for mining contracts in Peru (close to 59% of labor) and became predominant during the last 20 years by allowing the main company to transfer specialized jobs to other companies, thereby increasing or maintaining its productivity and efficiency at lower costs [5]. In this sense, outsourcing is defined as "...a form of business organization in which a main company commissions or delegates the development of one or more parts of its core business to one or more outsourcers, who provide work or services associated with or integrated into the former" [12].

In 2002, the ILO mentioned in its report "Work, Safety and Occupational Health Conditions in Mining in Peru" [5] that legislation at that time showed tendencies toward liberalization of the market, calling into question job security. Indirect hiring methods became popular in the last 20 years, to the detriment of direct methods of ongoing relations between main companies and workers. Nevertheless, this trend led to formation of "pro-job security" mechanisms, such as the increased prevalence of long-term (5-year) collective-bargaining agreements in some main companies [13].

Currently there is a legal framework that covers both workers' health and safety as well as labor conditions under outsourcing regimens. Among them is Law 29783, the Labor Health and Safety Act, and its amendment by Supreme Decree 006-2014-TR; Law 27626—the Mediation Act together with its Supreme Decree 003-2002-TR—Rules for Mediation (and amendments), and Law 29245 (which regulates outsourcing services) together with its Legislative Decree 1038 and Regulations, in Supreme Decree 006-2008-TR [14,15]. On the other hand, this legal framework is relatively new for those miners that have already been exposed to this type of work for several decades.

We have not found any studies that assess the connection between the duration (years) of outsourced employment as a system of mining hiring and the development of pneumoconiosis. Within that framework, the goal of this study is to evaluate the existence of an association between the duration of work under the outsourcing system and the development of pneumoconiosis among Peruvian mine workers that have applied to the National Center for Occupational Health and Environmental Protection for Health (Spanish acronym CENSOPAS) between 2008 and 2011.

MATERIALS AND METHODS

DESIGN AND LOCATION OF THE STUDY

We studied cases and unmatched retrospective control cases from CENSOPAS from 2008 to 2011. CENSOPAS is the technical, regulatory, and investigative agency for occupational health at the national level. It is an agency of the National Health Institute of Peru (Spanish acronym INS) and is in charge of investigating and issuing recommendations to prevent health risks in the workplace and diagnosing occupational diseases (such as pneumoconiosis) [16].

THE POPULATION AND SAMPLE

The study population consisted of all the mine workers examined by CENSOPAS between 2008 and 2011. Workers apply to this institution to get periodic medical occupational checkups either voluntarily or through institutional agreements. The word "miner" means a worker

hired by a company (main or outsourcer) who carries out activities related to the extraction, production, and cleaning of precious metals or activities related to the development of the mine (supervision and operation of heavy machinery among others) for a certain period of time.

The size of our sample was calculated using the PASS® statistical software, v. 13.0. We worked with the formula for the design of cases and unmatched controls at a rate of four controls per case. We used the 95% confidence level, a power of 80%, and the expected odds ratio (OR) of 1.5. The percentage of exposed controls was 50% according to a report by the Ministry of Labor [17] (a company can have a maximum of 50% outsourced personnel). As a result, there was a minimum of 1781 participants for the expected association. A case was defined as a worker with a diagnosis of pneumoconiosis based on the chest X-ray images taken by a CENSOPAS occupational doctor, according to the ILO guidelines for the year 2000 [18]. The ILO classification of pneumoconiosis is based on first evaluating the quality of the X-ray data (good, acceptable [with or without technical defects], and unacceptable). X-ray images of quality up to acceptable with technical defects were used for the pneumoconiosis analysis. Parenchymal and pleural aberrations were then identified. Parenchymal anomalies were evaluated for the presence of small and large opaque regions. The criteria used for the former were as follows: abundance (it was considered pneumoconiosis after subcategory 1/1 according to Supreme Resolution 014-93 TR) [19], affected areas, shape, and size. Large opaque regions are those whose maximum length exceeds 10 mm and are classified into categories A, B, and C [18].

The following criteria were used for pleural aberrations: pleural plaques (location, calcification, and extension), angle obliteration, and diffuse pleural thinning [18]. Controls were defined as the workers evaluated during the same period, who during their last occupational medical checkup, did not meet the aforementioned X-ray criteria for pneumoconiosis. Workers with indeterminate diagnoses were not considered. Anamneses that did not contain the main variables documented adequately (pneumoconiosis diagnosis and employment duration by the system of hiring) were excluded, as were women (because their jobs were not directly related to mining work) and workers who had worked in mining for less than one year.

MEASUREMENT OF VARIABLES

The occupational medical history of CENSOPAS accumulates detailed information for each job, according to each mining company's policies. An interviewer, who is an occupational doctor, records the name of the company and employment duration (years and months) by mining activity (whether the worker was on the surface or underground) based only on the official documents issued by each of the companies that had hired the worker prior to the interview. Duration was defined as the sum of the months of employment at an outsourcer and main company, location of the mine (underground or above ground) for each of the companies where they worked, and total time as a mine worker. The above-ground or underground mining activity of the mine was recorded as a self-report in the occupational medical history.

All companies whose names appeared in the Mining Directory of the Peruvian Ministry of Energy and Mines were considered main or principal companies. An outsourcer was defined as "a company that provides services or work hired by a main company, through its own workers, who are under its exclusive subordination. Both contractors and subcontractors are considered outsourcers" [12].

The total number of months of employment was then calculated to generate the following variables: total mining work duration (total employment at any mining company, in months), duration of employment at the main company, duration of employment at an outsourcer, duration of employment underground, and duration of employment aboveground. These variables were entered numerically in months, which were later converted to years and categorized in blocks of 10 years. Additionally, sociodemographic variables were collected, such as age, the number of mining companies where they have worked (categorized in terciles), the place of birth and residence in mountains (yes/no), educational level (none, primary, secondary, or higher education), and hemoglobin (Hb) levels.

DATA ANALYSIS

A database was created in Microsoft Excel via double entry. The data underwent quality control, and the database was then exported to the STATA 11.0 statistical software (STATA Corp., Texas, USA). Numerical variables (age, duration of employment, and hemoglobin)

did not conform to a normal distribution according to the Shapiro-Wilk test; therefore, they were expressed in medians and interquartile ranges. Categorical variables were expressed in absolute and relative frequencies.
For the bivariate analysis, we used the Mann-Whitney *U* test for numerical variables and the chi squared test for categorical values. In order to evaluate the strength of association, we generated a multiple logistical regression model using the stepwise backward method, by entering all the variables that were significant according to the bivariate analysis. During this part of the analysis, we eliminated the variables with greater p values until we obtained the final model by means of those variables that showed a significant p value. We excluded two variables due to collinearity (total duration of mining work and having been born in the mountains). We verified the fit of the model using the Hosmer-Lemeshow test. Finally, we calculated the crude and adjusted ORs (AORs) of the variables in the final model with their respective confidence intervals at 95%. Differences with $p < 0.05$ were considered statistically significant.

ETHICAL CONSIDERATIONS

The study protocol was approved by the Ethics Committee of the Peruvian University of Applied Sciences (PI021-12) and The National Health Institute of Peru. There were no consent forms because the data came from secondary sources and were collected anonymously.

RESULTS

The total sample consisted of 1910 workers who received medical occupational checkups at CENSOPAS between 2008 and 2011. We analyzed all cases (n = 391) and controls (n = 1519). For both cases and controls, the median age was similar (55; interquartile range [IQR]: 16 versus 58; IQR: 15; p = 0.20) as well as the total duration of mining employment in months (257; IQR: 151 vs. 252; IQR: 192; p = 0.19). Regarding the location of the mine, the median of underground employment in months was 211 (IQR: 173) for cases and 100 (IQR: 231) for controls ($p < 0.001$). According to the type of company, the median of duration of employment at a main company in months was 232 for cases (IQR: 247) and 223 for controls (IQR: 237; p = 0.93). The median Hb level was 16 for cases (IQR: 3.1) and 15.7 for controls (IQR: 2.8; p = 0.001).

Cases worked longer underground and at main companies than controls did, and there were significant differences between the two groups in duration of underground employment, aboveground employment, and outsourced employment ($p < 0.001$). Most cases and controls were born in the mountains (86.7% and 79.5%, respectively). The mountains remained the main place of residence for cases (63.9%), with a lower percentage among the controls (47.9%). We found significant differences between pneumoconiosis and being born and currently living in the mountains ($p < 0.001$). Regarding education, nearly a third of the workers attended no classes (27.1%), whereas the remaining two-thirds (approximately) had completed primary or secondary school (38.5% and 37%, respectively; $p < 0.001$). Participants' characteristics are presented in Table 1.

Table 1. Features of cases and controls: Peruvian miners examined by the National Center for Occupational Health and Environmental Protection for Health. 2008–2011

Males	Cases		Control		Valor *p*
	n	(%)	n	(%)	
Living in the mountains					
Yes	250	(63.9)	728	(47.9)	<0.001
No	141	(36.1)	791	(52.1)	
Education					
None	250	(16.2)	106	(27.1)	<0.001
Elementary	171	(43.7)	595	(38.5)	
Secondary	103	(26.3)	571	(37.0)	
Higher education	11	(2.8)	129	(8.4)	
Number of companies*					
1	122	(31.2)	567	(37.3)	0.054
2-3	155	(39.6)	562	(37.0)	
4-18	114	(29.2)	390	(25.7)	
Total duration of employment					
< 10 years	29	(7.4)	233	(15.3)	<0.001
10 - 20 years	146	(37.3)	475	(31.3)	
20 – 30 years	141	(36.1)	471	(31.0)	
> 30 years	75	(19.2)	340	(22.4)	
Duration of employment at main company					
Did not work	56	(14.3)	201	(13.2)	0.595
< 10 years	60	(15.4)	263	(17.3)	
≥ 10 years	275	(70.3)	1055	(69.5)	
Tiempo de trabajo tercerizado					
Did not work	278	(71.1)	1195	(78.7)	<0.001
< 10 years	52	(13.3)	193	(12.7)	
≥ 10 years	61	(15.6)	131	(8.6)	
Duration of outsourced work					
No trabajó	55	(14.1)	625	(41.2)	<0.001
< 10 years	39	(10.0)	205	(13.5)	
10 - 20 years	130	(33.2)	327	(21.5)	
> 20 years	167	(42.7)	362	(23.8)	
Total aboveground work					
Did not work	304	(77.7)	804	(52.6)	<0.001
< 10 years	19	(4.9)	131	(8.6)	
10 - 20 years	24	(6.1)	164	(10.7)	
> 20 years	44	(11.3)	430	(28.1)	

* Per terciles

Table 2. Factors associated with pneumoconiosis among Peruvian miners examined by the National Center for Occupational Health and Environmental Protection for Health. 2008–2011

Variables	Crude model			Adjusted model*		
	OR	(IC 95%)	Valor *p*	AOR	IC 95%	p value
Duration of outsourced work						
Did not work	1.00	Reference		1.00	Reference	
≥ 10 years	2.00	(1.43–2.79)	<0.001	1.50	(1.05–2.14)	0.026
< 10 years	1.16	(0.83–1.62)	0.387	1.21	(0.83–1.75)	0.317
Living in the mountains						
No	1.00	Reference		1.00	Reference	
Yes	1.93	(1.53–2.42)	<0.001	1.40	(1.10–1.78)	0.007
Educational level						
Higher education	1.00	Reference		1.00	Referene	
None	4.84	(2.51–9.33)	<0.001	3.07	(1.55–6.08)	0.001
Elementary	3.25	(1.71–6.15)	<0.001	2.35	(1.21–4.55)	0.011
Secondary	2.06	(1.07–3.95)	0.030	1.69	(0.86–3.32)	0.122
Total duration of underground work						
Did not work	1.00	Reference		1.00	Reference	
> 20 years	5.24	(3.76–7.30)	<0.001	8.92	(4.36–18.25)	<0.001
10 - 20 years	4.52	(3.21–6.36)	<0.001	6.87	(3.39–13.92)	<0.001
< 10 years	2.16	(1.39–3.35)	0.001	3.15	(1.59–6.24)	0.001
Total duration of aboveground work						
Did not work	1.00	Reference		1.00	Reference	
> 20 years	0.27	(0.19–0.38)	<0.001	2.23	(1.08–4.61)	0.030
10 - 20 years	0.38	(0.24–0.60)	<0.001	2.21	(1.13–4.34)	0.020
< 10 years	0.39	(0.24–0.65)	<0.001	0.85	(0.49–1.47)	0.562

*Multiple logistical regression using the stepwise backward method. Hosmer-Lemeshow test result: 0.79

Table 2 shows the multivariate logistical regression model that best fitted the sample (degree of adjustment: 0.79). Working for 10 or more years for an outsourcer was significantly associated with an increased frequency of pneumoconiosis (p = 0.026; OR 1.50; 95% CI 1.05–2.14), even after adjustment for living in the mountains, educational level, and duration of underground or aboveground employment.

DISCUSSION

The results show an association between pneumoconiosis and employment at an outsourcer for 10 or more years. As previously mentioned, the development of the labor market in the last two decades involved incorporation of this hiring system, which initially did not have a legal basis as it currently does. Nonetheless, this situation did not occur only in Peru but in many other countries worldwide as well. Matthew and Quinlan reported in their study that self-reported injuries are threefold more frequent among textile workers under the outsourcing system than among workers hired directly by the company [21]. In the mining-metallurgy field, some studies have reported that outsourced workers show higher morbidity and mortality from cancer, especially respiratory types, than do those who were not outsourced [22,23]. For the above reasons, the importance of government regulations becomes evident in terms of occupational-hygiene measures for all types of companies in order to ensure the safety of jobs, so that they do not become detrimental to the health of miners.

In this study, we found that workers had been exposed to occupational hazards for a long time because more than two-thirds of the total mining population had been working in this field for over 10 years. The study on Peruvian miners by Garces-Carbonell *et al.* also mentions the prolonged time of exposure and even shows an association between pneumoconiosis and the duration of mining employment (14.7 ± 4.3 [mean ± standard deviation]; p < 0.001) and age (42 ± 6.6; p < 0.001) [24].

Additionally, the results show that workers are eightfold more likely to develop pneumoconiosis if they had worked underground for more than 20 years. It is important to take into account that underground work involves closer contact with dust, given the aforementioned conditions such as inadequate ventilation in underground mines. This notion is consistent with the literature, namely, that an increased risk of pneumoconiosis is linked to greater exposure to occupational hazards [7-11].

One of the important issues for miners is the use of personal protective equipment, such as facial protectants: masks and special respiratory equipment for protection against gases and dust, depending on the job. Nevertheless, the 2002 ILO document on the work, safety, and occupational health conditions in mining in Peru states that despite the mining safety and hygiene regulations on the proper use, replacement, and training of personnel regarding personal protective equipment, miners reported a lack of adequate materials, having to buy their own supplies before being hired, or that the protective equipment wore out quickly and was not replaced, as reported by some workers, some of them outsourced [5].

Additionally, miners who developed pneumoconiosis were three times more likely to not have had any education than those who did not develop this disease. There is evidence that workers with less education are at a higher risk of getting sick [25-27]. This may be because more education implies better self-care as well as a better understanding during training sessions on the importance of different protective measures and their proper use.

On the other hand, living in the mountains was also found to be a risk factor. This may be because those who live in the mountains are exposed to mining work from an early age (because most mines are located in the mountains) and can start working very early, even unofficially. This would cause longer exposure time and less protection and therefore a greater risk of pneumoconiosis in the short term. An important factor is the altitude at which the mines are located, because according to Quispe [28] and Ruiz [29], high altitudes accelerate the development of pneumoconiosis. It is believed that at a higher altitude, there is lower atmospheric pressure of oxygen, which the human body uses to increase its respiratory capacity (by bathypnea and bradypnea) as a compensatory mechanism. This situation causes a greater intake of air during each breath, thereby increasing the amount of particles that are breathed in.

This study has some limitations. The exclusive analysis of miners examined at CENSOPAS causes a selection bias because these miners do not represent the total population of mine workers in Peru. Nonetheless, the main goal of this study was to identify a possible connection; therefore, this bias should not have significant implications for our results. On the other hand, there are variables associated with pneumoconiosis that could not be evaluated because they were not recorded in a medical history. These variables include the concentration of free silica in the dust inhaled by each worker and a history of unofficial employment (under precarious work and safety conditions). The concentration of silica in dust, in particular, cannot be determined other than by visiting the mines where the miners work; this was not possible given the characteristics of our study. These variables were not evaluated in this study because they were not recorded at the source of data collection. Furthermore, we did not evaluate the use of personal protective equipment because there are no records per company (only the last one is considered), even though this is a variable important for the development of pneumoconiosis.

In conclusion, we did find a significant association between pneumoconiosis and the duration of employment under the system of outsourcing as well as duration of employment underground, not having an education, and living in the mountains. Accordingly, drafting of regulations and laws to protect workers in hazardous jobs is important; thus, it is necessary to implement strategies to reduce the incidence of pneumoconiosis and other occupational diseases, and thereby to improve the quality of life of miners in Peru. Finally, we recommend new assessments on this subject on a temporary basis after implementation of the new Occupational Health and Safety Act of 2011.

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