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Full Length Research Paper

Evaluation of the risk of coal workers pneumoconiosis (CWP): A case study for the Turkish hardcoal mining

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Occupational lung diseases such as coal workers pneumoconiosis coal workers pneumoconiosis (CWP) in mines are attributed to many factors. In this study, an attempt has been made to estimate the risk of pneumoconiosis for miners, accounting for their individual and workplace characteristics in Turkish hardcoal mines. Logistic regression modeling is used to assess the association between risk factor and probability of CWP occurrence. The case study results have revealed that individual and workplace characteristics of the miners have some significant effect on the risk of pneumoconiosis. It has been found that average workplace dust concentrations, occupational categories, and collieries bear some insignificant difference in their CWP susceptibility. However, duration of exposure, age of first exposure to dust, and workers' educational background show significant differences in their risk of CWP occurrence. Based on the logistic model results, it has been inferred that, among the five collieries and occupational groups considered, Amasra colliery and face workers with elementary school education and exposure period over 15 years are more susceptible towards CWP compared to the others.

Key words: Occupational disease, pneumoconiosis, coal workers, coal workers pneumoconiosis (CWP), risk, logit, logistic model.

INTRODUCTION

Coal workers' pneumoconiosis (CWP) is a slowly progressive occupational lung disease caused by the inhalation and retention of airborne coal mining dust within the lungs. CWP is a preventable, but incurable lung disease of which severity depends primarily on the cumulative mass of coal mine dust inhaled. Especially those who have worked underground for many years are at risk of developing CWP even at low levels of dust exposure. The occurrence of CWP and its rate of progression are related to many factors such as concentration of respirable coal dust, dust size and composition, free silica content, coal rank, the duration of exposure, age, work environment and work practices of workers, which increase cumulative mass of dust inhaled and retained in the lungs (Stoces and Jung, 1962; Kenny et al., 2002; Antao et al., 2005; Attfield et al., 2007; McCunney et al., 2009; van Zyl and Obenour, 2009). The key to CWP is prevention of exposure through effective industrial hygiene measures that reduce airborne dust in the mine atmosphere.

Evidence from previous studies indicates diminishing CWP prevalence in the US overtime (Attfield and Althouse, 1992; Goodwin and Attfield, 1998; MMWR, 2003, 2004; Scott et al., 2004). The study by Scott et al. (2004) showed that CWP rate (per 10000) for US coal mining first increased from 4.1 to 26.1% between 1983 and 1987 then gradually decreased to 2.2% in 2001. This decrement in CWP rates was associated with the improvement of working conditions and stringent dust control measures in the workplaces (Antao et al., 2005). International acceptance of better control of dust emissions and more stringent regulations have led to a decrease in incidence of CWP and other lung related diseases especially in industrial countries (Vuyst and Camus, 2000; Singh and Davis, 2002). However, in developing countries, increased coal productions along with poor workplace conditions have exposed more and more miners to the adverse effects of coal dust and related lung diseases. For example, in China, the reported CWP prevalence rates among coal miners before the recent mining boom were estimated by some authors as 6% (Ninness, 2005; Langard, 2006). This percentage may seem small, but this is equivalent to about 60 thousand CWP occurrences per annum.

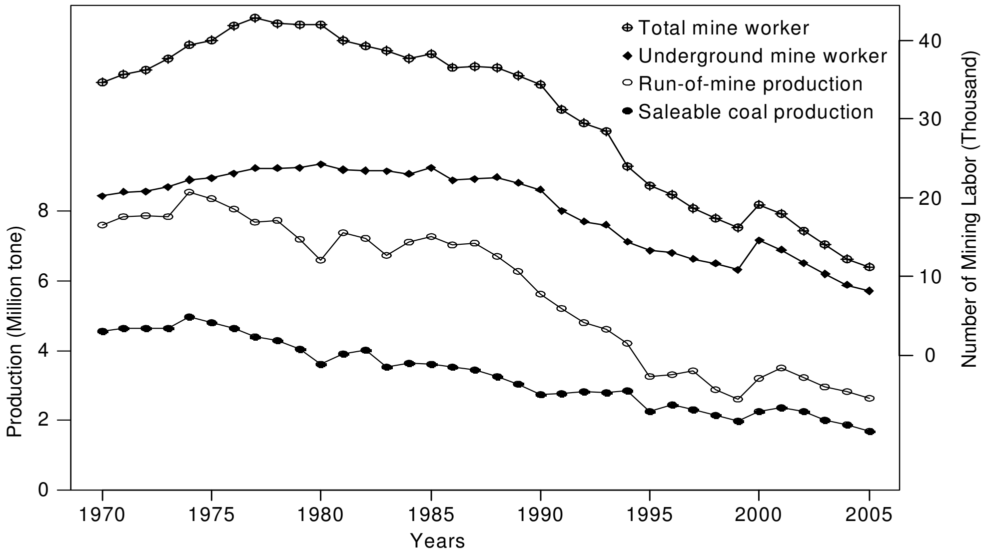

Figure 1. Number of annual mine labor and coal production in TTK (TTK 2010).

Hardcoal production in Zonguldak basin of Turkey dates back to 1850s. Several administrative periods have been observed since then. In 1936, the Turkish government took steps toward nationalization of Zonguldak coalfields and placed them under the management of Etibank (a national bank). Etibank, then, established a state coal company, Eregli Coal Mines (EKI) in Zonguldak. Later, in 1957, the administration of EKI was handed over to Turkish Coal Enterprises (TKI). Coal production was continued under the direction of TKI until 1983, when another state company Turkish Hardcoal Enterprises (TTK) was founded in Zonguldak, and all coalfields in the region were handed over to TTK. Today, hardcoal production in the basin still continues under the direction of TTK.

This study was conducted a retrospective investigation of CWP at TTK collieries. The objective of this study was to establish a quantitative assessment of the exposure-response relationships between risk factors and the occurrence of CWP. The risk of CWP among underground miners was investigated trough the use of a logistic regression modeling that accounted for individual characteristics (age, educational background, occupation, and working time) and workplace features (average dust concentrations and collieries).

MATERIALS AND METHODS

Study settings

TTK is the main hardcoal producing entity in the Zonguldak hardcoal basin which is located in the north-western Turkey. This basin is the only region in Turkey where hardcoal is produced. In the basin, there are three coal-bearing formations which are interpreted to be progradational delta to flood-plain sequence (Kerey, 1984). The formations contain about 60 coal seams with varying thicknesses from 0.05 to 5 m. The main features of these formations are as follows (Karayigit et al., 1998):

1. Alacaagzi formation comprises a succession of grey-greenish mudstones, siltstones and thin sandstones, with an upper unit containing thin (0.1 to 0.5 m) coal seams.
2. Kozlu formation consists of alternations of conglomerate, sandstones, siltstone, claystone and coal.
3. Karadon formation is dominated by sandstones and conglomerates with coals and subordinate siltstones and claystone. The lower part of the formation includes four mineable seams in the Amasra coalfield, and the upper part of the formation generally contains only very thin seams (about 5 to 10 cm).

The total reserve (proven, probable and possible) in the basin is estimated to be 1.3 billion tones. TTK operates five deep collieries which are Armutcuk, Kozlu, Uzulmez, Karadon, and Amasra, respectively from west to east in the region. Despite the great number of coal seams in the basin, only 22 are economically mined. These seams have an average thickness of 2 m and varying inclinations ranging form 0 to 90°. The principal mining method in the basin is retreating long wall mining with back-caving. The folded and faulted geological condition in the basin prevents application of mechanized extraction; therefore, coal production is carried out only with the use of pneumatic hand picks and explosives. Also, high-pressure air blasting technology is practiced in some seams which have a thickness of above 2 m and inclination above 45°. In the region, mining is extremely labor intensive because of limited application of mechanization in mining. Timber is exclusively used in coal face support. Galleries and gate roads are driven by drilling and blasting techniques and supported by steel arches. Underground transportation and haulage are carried out by belt conveyors and railways along the galleries, and then coal hoisted out to surface with the help of cages or skips operating within the shafts (Didari, 1988; TTK, 2009).

TTK coal production continues to decrease over time. Annual production in the last decade was about 2 million tones. Starting from 1980s, reduced employment in mining as a result of state policy has resulted in a decreased coal production (Figure 1). Saleable production went down by 56% from 1980 to 2005 (that is, from 3.6 to 1.6 million tones). The quality of the coal produced varies; the run-of-mine coal has an ash-content ranging from 15 to

Table 1. ISO and ASTM Classifications of Zonguldak hardcoal (TTK 2009).

Classification	Washeries			
	Armutcuk	Amasra	Kozlu-Uzulmez	Catalagzi
ISO				
ISO code	622	711	533-534	534
ISO class	VIA	VII	VC-VD	VC
Cokeability	Medium-weak	Medium-well	Very well	Very weak
ASTM rank				
ASTM scale	62-148	58-139	68-154	69-155
ASTM class	II-Bt	II-Bt	II-Bt	II-Bt
ASTM group	Hv Ab	Hv Bb	Hv Ab	Hv Ab

48%, low (less than 1%) in sulphur, and varying coking properties with a volatile matter of 30 to 35%. The calorific value of the run-of mine coal ranges from 4,500 to 6,000 kcal/kg. Typical coal characteristics according to the International Classification System of hard coals by type are given in Table 1. The coal produced in the region is mainly used in domestic industries. The coals which have good coking properties are mainly used in Turkish iron and steel industry, while the coals with low coking properties are mainly used as fuel in power generation, cement, and brick works (Guney, 1967; Karayigit et al., 1998; TTK 2009).

Study population

This study covered all underground miners who had been working prior to 2005. The miners were then still working in the company or just retired. Every investigated miner had a detailed record of job title, formal education, birth date, date for starting work at mines, the colliery they worked, and CWP status (diagnosed by the Zonguldak occupational disease hospital during periodic chest-radiograph examinations).

Most of the data in this study were elicited from personnel records of the Manpower Resource Section of TTK. The details of CWP contracted workers and dust records of workplaces were provided from the Directorate of Occupational Safety and Education of TTK. Number of years to contract CWP was found by the difference between the date for starting work and the date when the worker was diagnosed with the disease. Occupational categories were divided into five groups according to the way a miner was exposed to dust. Table 2 summarizes the variables selected for this study.

Dust exposure

Respirable coal mining dust is composed of coal and minerals mainly consisting of clays and some quartz. Dust concentrations for the workplaces are provided from TTK's historic dust sampling data. Dust sampling has been carried out irregularly with gravimetric dust samplers during monitoring of the workplaces. Representative exposure values for the specific workplaces (that is, coal face, tunnels/galleries, etc.) are an average of dust concentrations calculated from these samples. Table 3 shows a summary of results for the respirable dust concentrations for various workplaces at TTK collieries. Concentration of respirable dust showed considerable variation across mines and workplaces.

The highest values of dust concentration were observed in the faces with a mean value of 2.39 mg/m^3. Even though the observed values are less than 5 mg/m^3 which is current respirable dust exposure limit in Turkey (MLSS 1990), it is well over the accepted limit of 2 mg/m^3 in the US and considering the discussion of lowering this limit value in some industrialized countries. Most of the internationally accepted dust exposure standards require a reduction in permissible exposure limit (PEL) as the silica content of the dust increases since the respirable quartz dust is a known etiologic agent of pulmonary fibrosis (Harrison et al., 1997). PEL for respirable mine dust in Turkey has been limited to 5.0 mg/m^3 if silica content is less than 5%. If it is more than 5%, then the cut-off level is calculated from "25/silica %" relation (MLSS 1990). There is limited information regarding the silica content of respirable dust in TTK collieries. One study using 60 dust samples taken from Karadon colliery showed an average of 16.74% silica content (ranging from 6.39 to 35%) (Gebedek et al., 1999). This is above the Turkish PEL and requires remedial actions.

Statistical analysis

The analysis was conducted using the logistic regression model, because of the categorical nature of the dependent variable. Logistic regression is a statistical method used to assess the probability of occurrence of an event. It makes use of several predictor variables that may be either numerical or categorical. The likelihood of a disease or health condition is estimated as a function of a risk factor and covariates (Maiti and Bhattacharjee, 2001). Consider a collection of p independent variables denoted by the vector $x' = (x_1, x_2, \ldots x_p)$. The logit of the multiple logistic regression model is given by the equation

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots.. + \beta_p x_p, \quad (1)$$

In which case the logistic regression model is

$$\pi(x) = \frac{e^{g(x)}}{1 + e^{g(x)}}. \quad (2)$$

Where x = (1, x1, x2…xp) is the covariate vector and β = (β0, β1, β2............ βp) is corresponding parameter vector (Hosmer, 2000; Maiti and Bhattacharjee, 2001).

A step-by-step multivariate logistic regression was conducted to estimate the odds of CWP for the various variables with their categories. Based on the risk factor of CWP and availability of data, the variables chosen in this study are: miners' age at the start of work, miners' formal education, exposure duration (working time in:

Table 2. Characteristics values of coal miners with and without CWP.

Number of underground miners	Without CWP	With CWP
	7213	**1302**
Job (occupational category)		
Face workers	3062	509
Haulage workers	1206	328
Tunnel/gallery workers	1317	194
Superintendents	530	133
Others	1098	138
Collieries		
Armutcuk	824	150
Amasra	645	160
Uzulmez	1636	328
Karadon	2755	457
Kozlu	1353	207
Formal education (average, years)	6.41	6.04
Working period (average, years)	11.45	16,72
Age of first exposure to dust (years)		
<20	344	57
20-24	2923	488
25-29	3393	580
30-34	539	162
>35	14	15
Period to contract CWP (years)		
<5	-	147
5-9	-	230
10-14	-	365
>15	-	560

years), occupation, and amount of average dust concentration for the workplace, collieries, and the status of disease. Following the coding scheme (Table 4) of the variables, the logistic model is specified as follows

$$\text{Probability of cwp} = \text{f}\left(\text{mine, occu, edu, age, dur, dust}\right) \quad (3)$$

$$\pi(cwp) = \frac{e^{\beta_0+\sum_{i=1}^{4}\beta_{1i}mine_i+\sum_{i=1}^{4}\beta_{2i}occu_i+\beta_3 edu+\sum_{i=1}^{3}\beta_{4i}age_i+\sum_{i=1}^{3}\beta_{5i}dur_i+\beta_6 dust}}{1+e^{\beta_0+\sum_{i=1}^{4}\beta_{1i}mine_i+\sum_{i=1}^{4}\beta_{2i}occu_i+\beta_3 edu+\sum_{i=1}^{3}\beta_{4i}age_i+\sum_{i=1}^{3}\beta_{5i}dur_i+\beta_6 dust}} \quad (4)$$

Where βji are corresponding parameters of the covariates and they are as follows:

β1i = dummy parameters for TTK colliers
β2i = dummy parameters for miners' occupation categories
β3 = dummy parameters for miners' education categories
β4i = dummy parameters for the age categories
β5i = dummy parameters for duration of dust exposure categories
β6 = parameters for amount of mean dust concentration

The β parameters of the logistic model were estimated by the maximum likelihood methods. The validity of the model in this study was first checked by examining the statistical level of significance for its coefficients using deviance statistic. The tests that whether the β coefficients are zero or not, were performed based on Wald chi-square statistics for each variable in the fitted model (Maiti and Bhattacherjee, 1999; Maiti and Bhattacharjee, 2001; Palei and Das, 2009).

RESULTS AND DISCUSSION

CWP in Zonguldak hardcoal basin initially was recognized as a problem in the early 1960s with the increased court applications of affected miners for compensation benefits (Didari, 1988). The recognition of CWP as an occupational disease led the state mining company (EKI) to take some preventative measures. First, dust concentration measurements were initiated to determine the amount of dust exposures, and the workplaces were grouped depending upon the amount of

Table 3. Concentration of coal dust (mg/m3) in the collieries and workplaces of TTK.

Mines	Mean	Standard deviation	Maximum
Armutcuk	2.08	0.42	26.4
Karadon	1.92	0.33	26.3
Kozlu	1.78	0.50	30.8
Amasra	1.68	0.24	13.8
Uzulmez	1.21	0.18	11.9
Work place			
Face	2.39	0.39	21.6
Gateroad	1.43	0.26	20.3
Hauling	1.16	0.16	30.8
Gallery	1.06	0.14	29.1
Overall	1.75	0.34	30.8

Table 4. Logistic regression coding scheme.

Variables	Description	Coding
CWP	Miners' health status (whether one have CWP or not)	1: CWP present
		0: No CWP
Occupation	Miners' occupation	0: others * a
		1: superintendent
		2: tunneling
		3: haulage
		4: face worker (miner)
Mine	Collieries of TTK	0: Armutcuk *
		1: Amasra
		2: Uzulmez
		3: Karadon
		4: Kozlu
Education	Miners' education	0: edu=5 * years (only primary school)
		1: edu>5 years
Age	Age at first exposure to dust (age at the start of work, in years)	0: age<20 *
		1: 20≤age<25
		2: 25≤age<30
		3: age≥30
Duration	Duration of dust exposure (working time until 2005, in years)	0: dur<10 *
		1: 10≤dur<15
		2: 15≤dur<20
		3: dur≥20
Dust	Amount of mean dust concentration in workplaces (calculated from the historical data for the workplaces, mg/m3)	-

* Reference category. a: Dispatcher, mechanic, electrician, repairman, etc.

Table 5. Occurrence of CWP from 1970 to 2005 in Zonguldak hardcoal basin (Karacelebi 1979; Buzkan and Ofluoglu 1992; Usman and Ozturk 2006).

Years	1968-1969*	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004
Total CWP	**3196**	**1548**	**1126**	**3153**	**1375**	**1669**	**1759**	**1055**
Annual CWP	-	310	225	631	275	334	352	211
Annual number of underground miners (average)	20600	21000	23400	23500	22600	17500	12300	11800
(CWP rate per 1000)		(14.74)	(9.62)	(26.83)	(12.17)	(19.07)	(28.60)	(17.88)
Annual number of total workers (average)	35200	36700	41700	39500	36700	29500	18800	13000
(CWP rate per 1000)		(8.44)	(5.40)	(15.96)	(7.49)	(11.32)	(18.71)	(16.23)
Total production (saleable-Million tonnes)	-	23.46	22.20	18.70	16.89	13.96	11.14	10.75
(CWP per Million tonnes)		(65.98)	(50.73)	(168.62)	(81.43)	(119.53)	(157.97)	(98.14)

*CWP screening program first started in 1968.

dust concentration. As a result of this effort, considering the dust concentrations, workplaces were grouped into four categories: dust-free (0-2 mg/m^3), low-dust (2 to 4 mg/m^3), dusty (4 to 5 mg/m^3), and very dusty (5 to 10 mg/m^3). Also, working in the workplaces with a dust concentration above 10 mg/m3 was restricted (MLSS, 1990). Then, in 1968, the first CWP screening program (with micro films) was initiated for early detection of CWP. The screening started with senior miners, and early findings showed 2350 CWP occurrences among 35 thousand miners (Karacelebi, 1979). Table 5 shows the summary of findings of the CWP screening in the basin for the period of 35 years (1970 - 2005) with 5 year intervals. Starting from 1970, on average, 330 miners contracted CWP annually. Even though the number of workers and production fell down significantly over the years (Figure 1), the number of CWP cases per annum did not changed substantially. Thus, the overall CWP rate (per 1000 person) from 1970 to 2005 went up from 8.44 to 16.23. The rate of CWP per million tones of coal produced also rose from 66 to 98 in the same period. It is difficult to explain reasons of this CWP rate increases since “the pneumoconiosis related studies in Turkey were limited (Ozturk et al., 2005; Cimrin, 2006)”. However, one can speculate few reasons for such increases. For example, introduction of standard films in the screening in 1990 and improvements in the medical technology may have increased the detection rate in the last decade. But, more likely, insufficient improvements in the workplace atmosphere could be the main cause as a result of;

1. Failure to control daily respirable dust exposures of miners below the permissible exposure limits,
2. Failure to comply with continuing measure for controlling dust during mining operations,
3. Absence of a dust control measures targeted for the mining conditions, and
4. Lack of an enforcement regime for respirable silica.

Overall, CWP among Zonguldak coal miners is still the most important health problem. Simple comparison of CWP rates between the US coal mining industry (mean CWP rate of 10 per 10000 from 1983 to 2001 (Scott et al., 2004) and Zonguldak hardcoal basin (14 per 1000 from 2004) shows that the occurrence rate of CWP among Zonguldak miners is 14 times higher than that of the US coal miners.

Stata (v.8) software was used for the logistic model runs (Stata 2003). The βj parameters expressed in Equation 4 were estimated using the Stata logistic routine. The best relationships of CWP with the contributing parameters are tabulated in Table 6 with the logistic model coefficients (βj) and odds ratio. The significant parameters are indicated by an asterisk at 0.05 probability level of significance. The results indicate that mine, occu, edu, age and dur variables show some significant effects, while dust variable is not statistically significant at 5% level; yet, the deviance test for dust is significant.

The mine (collieries) category shows that the conditions in Amasra, Armutcuk, Karadon and Kozlu are significantly related to occurrence of CWP while in Uzulmez it is insignificant. The results indicate that Amasra colliery is three times riskier than Kozlu colliery. The occupation categories show that the face workers are significantly different than reference group in the occurrence of CWP, while the others are insignificant. Age category shows significant positive results in each case, indicating higher occurrence of CWP as the age of employment increases. Duration categories are also positive and significant indicating the occurrence of CWP increases as the amount of miners’ exposure time increases. Furthermore, the occurrence of CWP is 5 and 20 times higher for the working time of 10-to-15, and 15-to-20 years,

Table 6. Estimated logistic regression outputs: coefficients with standard errors (SE), Odds ratio (OR) with confidence interval (CI) and probability for Wald statistics (p) for the model variables (*statistically significant variable at 5% level).

Variables	βj (SE)	OR (95% CI)	p>|z|
Mine			
Amasra	0.4 (0.165)	1.492 (1.08 – 2.06)	0.02*
Uzulmez	0.095 (0.151)	1.099 (0.82 – 1.48)	0.53
Karadon	-0.632 (0.123)	0.532 (0.42 – 0.68)	0.00*
Kozlu	-0.625 (0.141)	0.535 (0.41 – 0.71)	0.00*
Occupation			
Superintendent	0.324 (0.261)	1.382 (0.83 – 2.3)	0.21
Tunneling	0.033 (0.153)	1.034 (0.77 – 1.39)	0.83
Haulage	0.168 (0.14)	1.183 (0.9 – 1.56)	0.23
Face worker	0.424 (0.17)	1.528 (1.1 – 2.13)	0.01*
Age			
20≤age<25	0.463 (0.169)	1.589 (1.14 – 2.21)	0.01*
25≤age<30	0.947 (0.171)	2.577 (1.84 – 3.6)	0.00*
age≥30	1.822 (0.202)	6.182 (4.16 – 9.18)	0.00*
edu(1)	-0.864 (0.116)	0.421 (0.34 – 0.53)	0.00*
Duration			
10≤dur<15	1.71 (0.459)	5.531 (2.25 – 13.6)	0.00*
15≤dur<20	3.138 (0.378)	23.06 (11 – 48.33)	0.00*
Dur≥20	2.518 (0.398)	12.409 (5.69 – 27.06)	0.00*
Dust*dur(1)	-0.271 (0.242)	0.762 (0.47 – 1.23)	0.26
Dust*dur (2)	-0.246 (0.201)	0.782 (0.53 – 1.16)	0.22
Dust*dur (3)	1.049 (0.216)	2.855 (1.87 – 4.36)	0.00*
Dust	0.188 (0.204)	1.207 (0.81 – 1.8)	0.36
Constant	-4.996 (0.428)		0.00*
Log likelihood at zero = -3446.4		LR chi2(20) = 1851.93	
Log likelihood at converge = -2520.4		Prob > chi2 = 0.00	
Number of obs. = 8409		Pseudo R2 = 0.27	

respectively, compared to first 10 years. Significant and negative education category relates that as the level of workers' education increases, the occurrence of CWP decreases. This result may indicates that the educated workers are taking better prevention measure against CPW (that is, use of dust filters and masks), or they have better jobs (that is, jobs with less dust exposures). Dust and dur*dust (interaction) variables account for the amount of dust exposure that miners face, but the variables are insignificant. However, the positive sign on dust variable shows that the amount of dust that a miner faces in the workplace has some effects on CWP. There are certain limitations to this study that deserve elaborations. Many studies on CWP have demonstrated significant influence of smoking on health of the studied populations. Although influence of smoking on CWP is weak, it is an important confounding factor. In this study, there is no mention on the smoking habits of the miners (e.g. duration of smoking and number of cigarettes smoked daily). Because of the retrospective and large studied population, it is difficult to collect information on smoking habits of the miners.

In addition, dust concentration measures for the workplaces have some limitations. Since dust concentrations measures for the workplaces were based on average concentrations of irregular dust monitoring samples, this measure might not reflect the true cumulative dust exposure in the workplaces. However, since the amount of dust exposed is mostly related to workplace and type of work, the effect of dust exposure will be partly captured by the occupation variable; yet, the magnitude of the effect is still unknown. In summary, in terms of occupation of workers, duration of exposure and cumulative exposure of dust, the statistical findings related to the main causes of CWP are in accordance with the results reported in the literature.

Conclusions

CWP occurrence statistics showed an increase in Turkish hardcoal mining over time. The rate of CWP (per 1000 person) went up from 8.44 to 16.23 in the last 35 years. Despite 50% decline in production, no apparent improvement in the prevention of CWP has been achieved. This is in contrast to situations in developed countries. Various explanations might be considered for the continued occurrences of CWP. These include; inadequacies in the mandated dust regulations, failure to enforce those regulations, lack of innovative prevention measures to accommodate changes in mining practices, and inadequate screenings for early detection and, therefore, missed opportunities to take action to reduce dust exposure.

In this study, multivariate logistic regressions was used for assessing the association between risk factors and probability of disease occurrence by statistically adjusting for potential confounding effects of other covariates. The results revealed that individual features of workers, their occupation, and collieries showed distinct relationship with the occurrence of disease, indicating significant differences in pneumoconiosis susceptibility. Among these relationships, the occupation category revealed that the face workers are the most disease prone than the others. Therefore particular attention should be given this group of worker to reduce their cumulative dust exposure. The solution of the problem will be: development of work specific screening programs for early detection and taking necessary actions to reduce the miners dust exposure, development of new work regimes depending on the risk of occupational category (that is, workers who work in the riskiest job could be transferred to lower risk job after a specific amount of time), and taking additional prevention measures in high risk work environments (that is, use of protective equipment, dust suppressing solutions such as water spraying, additional ventilation, reduced working time for certain activities creating dust).

The mine category showed that the risk of CWP was particularly high at Amasra and Uzulmez collieries. This finding is due to the differences in geological characteristics of the collieries, mining environment, and work practices followed. Additional investigation (that is, determination of quartz content in respirable dust) should be conducted to assess the effects of these differences in Amasra and Uzulmez collieries. As expected, the duration of exposure had a significant effect. The risks of contracting CWP in the 10-to-15 and 15-to-20 years of working time were 5.5 and 23 times, respectively, higher than that of the first 10 years. To reduce the overall occurrence of CWP underground mine, workers can be transferred to less dusty work environment after certain amount of working time (that is, after 15 years). The amount of average dust concentration in workplaces had some effects related to increased risk of CWP. However, statistically, it was not enough to show individual exposure differences; therefore, the dust sampling frequencies and locations should be rescheduled. Also, according to the results, workers who started working at older ages were more likely to contract CWP than the younger group. This was probably due to the workers' prior dust exposure. Therefore, the workers who started working in mines at older age should be subject to medical examinations thoroughly.

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