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Evaluation of occupational injuries with lost days among opencast coal mine workers through logistic regression models

Seyhan Onder *

Department of Mining Engineering, Eskisehir Osmangazi University, Eskisehir, Turkey

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ABSTRACT

Despite precautions, mining remains the most hazardous occupation, and coal mining is one of the most dangerous industries for non-fatal occupational accidents. Accidents are complicated events with many factors that affect their formation, and statistical evaluation of accident records can produce valuable information that may prevent such accidents. In this study, a logistic regression analysis method was applied to non-fatal occupational injuries from 1996 to 2009 in an opencast coal mine for Western Lignite Corporation (WLC) of Turkish Coal Enterprises (TKI). The accident records were categorized as occupation, area, reason, age, part of body and lost days, and the SPSS package program was used for statistical analyses. Logistic regression analyses were used to predict the probability of accidents that resulted in greater or less than 3 lost workdays. It is found that the job group with the highest probability of exposure to accidents with greater than 3 lost workdays for non-fatal injuries was the maintenance personnel and workers. The employees were primarily exposed to accidents caused by a mining machine, and the lower and upper extremities have the highest probability of exposure to such risks. Finally, an equation for calculating the probability of exposure to accidents with greater or less than 3 lost workdays was derived. Then, the equation was used to determine the important accident risk factors.

1. Introduction

Compared with other industries, the mining industry and related energy resource industries are associated with high rates of occupational injuries and fatalities, and mining is one of the most hazardous work environments in many countries around the world (Sari et al., 2009; Groves et al., 2007; Bajpayee et al., 2004; Donoghue, 2004). Mining is a hazardous profession and considered at war with the unpredictable forces of nature. As a result, the mining industry continues to be associated with a high level of accidents, injuries, and illness (Maiti et al., 2004). Despite the record of progress in reducing mining fatalities and injuries, both the number and severity of mining accidents remain unacceptable (Kecojevic et al., 2007), and the incidence rates are high compared with other industries (Komljenovic et al., 2008). To identify the potential problem areas, it is necessary to investigate the causes of accidents and control exposure of such risks through quantitative analysis of accident data (Maiti et al., 2001).

Human factors approaches to system safety have been used to provide greater insights into the causes of accidents and can be applied to the mining context (Lenné et al., 2012). These models of human error in organizational systems take a systems approach (Reason, 2000). Such models have supported the development of several methods of accident investigation and analysis that use error and latent condition classification schemes to provide an analysis of the types of failure involved in accidents. One of the more widely used approaches is the Human Factors Analysis and Classification System (HFACS) (Shappell and Wiegmann, 2000). HFACS describes four levels of failure: (1) Unsafe Acts, (2) Preconditions for Unsafe Acts, (3) Unsafe Supervision, and (4) Organizational Influences (Shappell and Wiegmann, 2004). Reason proposed the "Swiss Cheese" model of human error where four levels of failure are described. Each level influences the next level as seen in Fig. 1 (Shappell and Wiegmann, 2000).

Lost workdays in mining industries are valuable indicators for a number of aspects in job safety programs (Coleman and Kerkering, 2007). According to the European Statistics on Accidents at Work (ESAW), the definition of a non-fatal accident at work is "The definition of what constitutes a notifiable work accident ranges from any work accident, whether it results in an interruption of work or not, to a minimum absence of more than three days". Accidents with greater than 3 days' absence from work are reported more than accidents with less than 3 days' absence from work. Only accidents with greater than 3 days' absence are considered in the ESAW methodology (EUROSTAT, 2001).

In this study, based on the ESAW accident definition, a logistic regression method was used for categorical data analysis to predict

* Tel.: +90 2222393750; fax: +90 2222393613.
E-mail address: sonder@ogu.edu.tr

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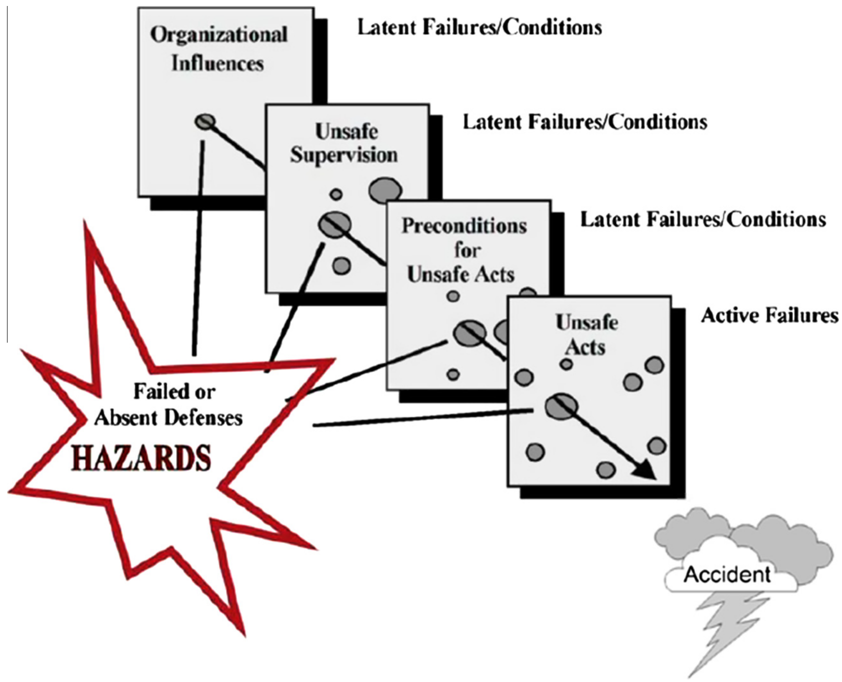

Fig. 1. The "Swiss Cheese" model of human error causation (adapted from Reason, 2000).

the probability of accidents with greater or less than 3 lost workdays. Occupational injuries for the Western Lignite Corporation (WLC) of Turkish Coal Enterprises (TKI), which is the primary state body of lignite coal production in Turkey, were examined. The accident records kept by WLC are reliable, detailed, well organized, and cover a long period. The records include the name of the employee, birth date, accident date, accident time, occupation (the job title of the worker), area (accident location), reason (accident type), body parts affected, and days off from work (Sari et al., 2004). The data used herein comprised occupational accidents from 1996 to 2009 in the opencast coal mine for the WLC. The accidents were categorized for occupation, area, reason, age, part of body as well as lost workdays, and the SPSS package program was used for logistic regression analyses.

2. Logistic regression analysis

Regression methods have become an integral component of any data analysis that describes the relationship between a response variable and one or more explanatory variables. Often, the outcome variable is discrete and comprises two or more possible values (Hosmer and Lemeshow, 2000). Logistic regression is a statistical method used to predict the probability of an event and is the most important model for categorical response data. Categorical data is a statistical data type consisting of categorical variables, used for observed data whose value is one of a fixed number of nominal categories, or for data that has been converted into that form, for example as grouped data. The explosion in the development of methods for analyzing categorical data that began in the 1960s has continued apace in recent years. Today, because of this development and the ubiquity of categorical data in applications, most statistics and biostatistics departments offer courses on categorical data analysis (Agresti, 2002).

Linear regression assumes that the expected value of Y for a given value of x may be expressed as an equation that is linear in x, such as $E(Y/x) = \beta_0 + \beta_1 x$. The specific form of the logistic regression model is as follows:

$$\pi(x) = e^{\beta_0+\beta_1 x}/(1 + e^{\beta_0+\beta_1 x}).$$

The logit of the multiple logistic regression model is determined using the following equation:

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p.$$

The logistic regression model is then the following (Hosmer and Lemeshow, 2000):

$$\pi(x) = e^{g(x)}/(1 + e^{g(x)}).$$

Multiple logistic regression was used to estimate the odds ratios for the accidents with greater or less than 3 lost workdays. Given the primary risk factors that affected such accidents, the variables used were occupation (x_1), area (x_2), reason (x_3), age (x_4), and part of the body (x_5). Because the data used in this study comprised categorical and continuous variables, logistic regression was used to predict the probabilities for accidents with greater or less than 3 lost workdays. Thus, herein lost workdays were used as the dependent variable and categorized as greater and less than 3 days.

$$\pi(x) = e^{\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_4x_4+\beta_5x_5}/(1 + e^{\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_4x_4+\beta_5x_5}).$$

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$: Coefficients of regression, and
x_1, x_2, x_3, x_4, x_5: Independent variables.

3. Risk estimation studies for the WLC

In the open pit mines of the WLC in the eastern part of Turkey, mining activities include overburden stripping and coal winning. For overburden removal, an excavator, truck, and dragline are employed, whereas, for coal winning, a hydraulic excavator and truck are used. Drilling is performed using drilling machines and an ammonium nitrate and fuel oil (ANFO) mixture is used for explosives (Sensogut and Cinar, 2007).

The number of persons employed in the WLC and injuries from 1996 to 2009 are shown in Fig. 2.

Fig. 2 shows a significant reduction in the number of accidents since 2004. In addition, the number of workers also decreased from

Fig. 2. Number of injuries and employees.

1996 to 2009. For the quantitative analysis of accident and injury data to measure safety performance and identifying safety problems, the following two basic indices, Accident Frequency Rate (AFR) and Accident Severity Rate (ASR), are typically used.

$$\text{AFR} = (\text{Total number of accidents}/\ \text{Total number of man-hours worked}) * 1000000$$

$$\text{ASR} = (\text{Total number of days-lost}/\text{Total number of man-hours worked}) * 1000$$

AFR is an expression that relates the number of specific accidents to the number of man-hours worked. The objective for the severity rate is to indicate loss from incapacity produced by occupational accidents. AFR is calculated by dividing the number of accidents (multiplied by 1,000,000) during a statistically relevant period by the number of man-hours worked by all persons exposed to the accident risk during the same period. The severity rate should be calculated by dividing the number of workdays lost (multiplied by 1000) by the number of hours of working time for all of the persons included (Sari et al., 2009). The AFR and ASR graphs for the WLC are presented in Figs. 3 and 4, respectively.

As shown in Fig. 3, although a significant variation is not observed in the accident frequency rates (except for 2008), the frequency rates tended to decrease. AFR, which measures how often workplace incidents occurred, has declined slightly since 1996, dropping from 13.25 per million man-hours worked in 1996 to 5.65 in 2009. This shows that there are fewer workplace incidents against the number of hours worked. The overall AFR was lower as compared to 2008. The reason for this, despite the decrease the number of employees, the number of accidents in 2008 remains high.

According to the ASR graphs in Fig. 4a, 1999, 2002, 2006, and 2007 have higher ASR than other years because of one fatal occupational accident in these years. It is expected that the number of lost workdays is higher for the year with a higher ASR. A fatal work accident is counted as 6000 lost working days in the USA and 6500 lost working days in England, but 7500 lost working days in Turkey (Kasap, 2011). Nearly 72% of accidents in WLC led to lost working days greater than 3. In order to observe the trend of the ASR in non-fatal accident years, the ASR values are plotted by excluding the fatal accidents (Fig. 4b). As seen from this figure, the ASR increases over the years. The accident severity rate (ASR) changed from 0.061 man-days lost for every thousand man-hours worked in 2001 to 0.262 in 2008 for the non-fatal accidents, from 1.323 in 1999 to 2.062 in 2007 for the fatal accidents.

Risks based on historical data are particularly easy to understand and are often reliably perceived. Therefore, it is easy to illustrate a risk calculated from historical data to understand certain characteristics of risk estimation (Wilson and Crouch, 1987).

In this study, the occupational injuries were evaluated for occupation, area, reason, age, part of the body and lost workdays. The occupation variable (OCCUPATION) has three categories: driver, worker, and maintenance personnel. The common responsibilities for the occupational job groups include driving trucks and mining machines for the drivers; drilling and blasting for the workers; arrangement and maintenance of the equipment used for the maintenance personnel. The area variable (AREA) has four categories, the opencast mining area, coal handling plant, workshops, and surface plants (facility areas except for the coal handling plant and workshops). The reasons for accidents that led to injuries (REASON) were categorized into five primary groups, struck by/falling object; manual and mechanical handling; machinery; mining machine; and hand tools. The age variable (AGE) was categorized into three groups: 25–34 yr, 35–44 yr, and 45–54 yr. The part of the body variable (PART OF BODY) was categorized into four groups: head, upper extremities (hand and arm), lower extremities (leg and foot), and torso. The lost workdays (LOST DAYS) variable was categorized into two groups: less than 3 days and greater than 3 days. Percentage distributions of age and occupation for all employees are given in Table 1.

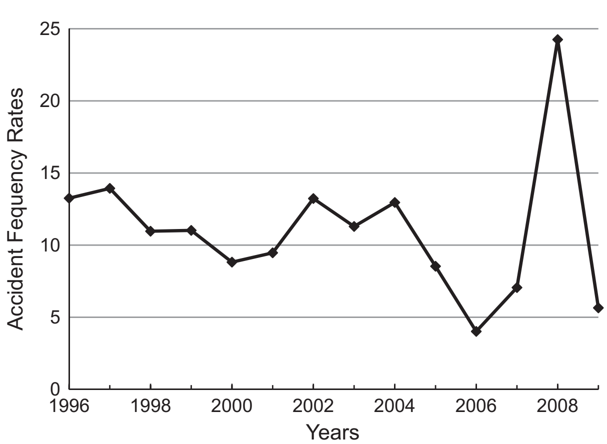

Fig. 3. Accident frequency rates from 1996 to 2009.

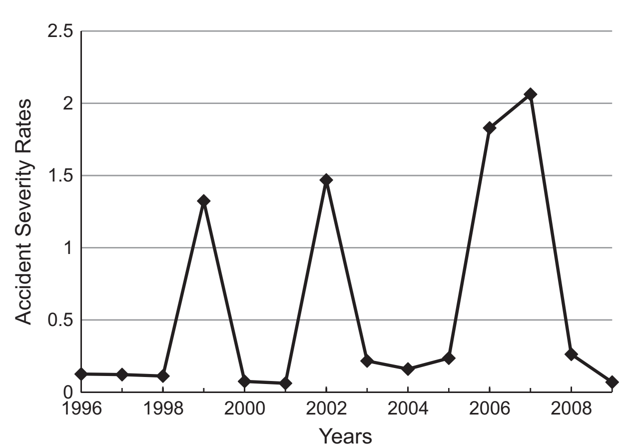

Fig. 4a. Accident severity rates from 1996 to 2009.

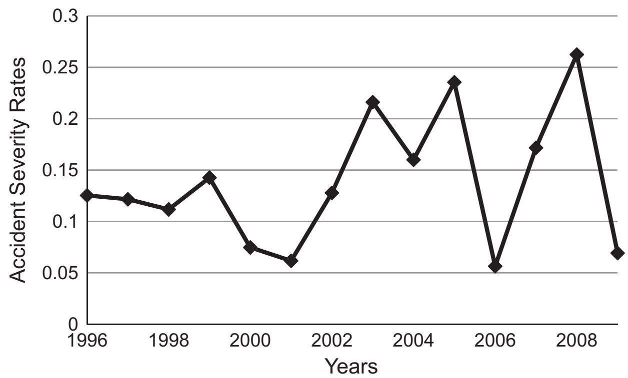

Fig. 4b. Accident severity rates from 1996 to 2009 excluding the fatal accidents.

Table 1
Percentage distributions of age and occupation for all employees.

Main categories	Sub categories	%
AGE	25–34	13.67
	35–44	21.72
	45–54	57.19
	Others	7.42
OCCUPATION	Worker	2.7
	Maintenance personnel	44.2
	Driver	31.1
	Others (administrative and social work staff)	22.0

The percentage distributions for injured employees and the occupation, area, reason, age, part of the body, and lost workdays are shown in Table 2.

As shown in Table 2, the largest proportion of injury accidents resulted from a mining machine (39.2%). The other reasons are ordered as follows: machinery (25%); manual and mechanical handling (16.7%); hand tools (11.9%); and struck by/falling object (7.2%). A total of 54.4% of injuries were in workshops. The other areas are ordered as follows: opencast mining area (21.1%), coal handling plant (18.9%), and surface plants (5.6%). The largest proportion of injuries (65%) was for the age group 35–44 yr. Further, 19.4% of injuries were for the age group 45–54 yr followed by the 25–34 yr group (15.6%). Maintenance personnel (79.4%) were more likely to be injured than workers (11.7%) and drivers (8.9%). In the percentage distributions for injuries shown in Table 2, the upper extremities (36.4%) were the most affected body parts from an accident injury followed by lower extremities (26.4%), torso (20.8%) and head (16.4%). The accidents with lost workdays greater than 3 days were 71.9%, while the accidents with lost workdays less than 3 days were 28.1% for all injuries.

Table 2
Percentage distributions for injured employees.

Categories	Effect name	%
REASON	Struck by/falling object	7.2
	Manual and mechanical handling	16.7
	Machinery	25.0
	Mining machine	39.2
	Hand tools	11.9
AREA	Workshops	54.4
	Coal handling plant	18.9
	Surface plants	5.6
	Opencast mining area	21.1
AGE	25–34	15.6
	35–44	65.0
	45–54	19.4
OCCUPATION	Worker	11.7
	Maintenance personnel	79.4
	Driver	8.9
PART OF BODY	Head	16.4
	Upper extremities	36.4
	Lower extremities	26.4
	Torso	20.8
LOST DAYS	Less than 3 days	28.1
	Greater than 3 days	71.9

The percentages of subcategories of the main accident reasons were determined and also, percentages of injured body part, area and occupational groups were calculated separately for each reason of the accidents (Table 3).

It was determined that occupational group having the highest percentage of all accidents is maintenance personnel. The workshops are the highest risk area and lower and upper extremities are the most affected part of the body. To reduce accidents and affected body part, special training to maintenance personal related to their profession should be provided. This education should include ergonomic hand carrying, careful use of hand tools, working at high, and importance of using personal protective equipment. When the subcategories of accidents are evaluated, it is found that the main causes of accidents are incorrect use of equipment, excessive workload than the worker can handle, inappropriate procedure, rule-based error, failure to identify the hazards involved in completing a task for unsafe acts, poorly designed equipment and environment, and mental or physical limitations for preconditions for unsafe acts.

4. Result and discussion

The data collected from the WLC were evaluated using a logistic regression analysis method for a detailed investigation of the factors that affect accident injuries. To examine the effects of independent variables on lost workdays, the significance values (p) were analyzed. If the significance values are less than 0.05 (95% confidence interval), the independent variables likely effect lost workdays. A simple binary logistic regression analysis was used for each independent explanatory variable to establish its statistical significance and possibility for inclusion in the model. The simple binary logistic regression analysis results are shown in Table 4.

B coefficients are the typical designation for an effect coefficient, and Exp(B) is the odds ratio (OR). The odds ratio is an effect size measurement. An odds ratio of 1 indicates no effect. An odds ratio greater than 1 indicates that the variable in question increases the odds, an odds ratio less than 1 indicates that the variable decreases the odds (Garson, 2008). If the odds ratio is greater than 1 and the lower bound of the confidence interval (CI) is not below 1, a proposed risk factor is likely a significant risk to accidents (Shephard, 2004). For all of the variables except for the 35–44 year old group, the coal handling plant as well as the manual and mechanical handling variables were statistically significant ($p < 0.05$). The job group with the greatest probability of exposure to accidents with greater than 3 lost workdays from non-fatal injuries was the maintenance personnel, and employees were most exposed to accidents from the mining machine. Additionally, the surface plant had the highest risk of exposure to non-fatal injuries with greater than 3 lost workdays. The age group with the highest risk of exposure to accidents was 25–34, and the upper extremities were most exposed to such risks. Although the least-injured part of the body was the head, head injuries resulted in greater than 3 lost workdays. When the odds ratios and confidence intervals were evaluated together, the possibility of exposure to non-fatal work accidents for maintenance personnel was three times more likely than for drivers. Despite the surface plant low accident rate (5.6%), when lost workdays were considered in the simple binary logistic regression model, the possibility for accidents with greater

Table 3
The percentages of subcategories of the main accident reasons, injured body part, area, and occupational groups.

Reason	%	Subcategory of accident reasons	%	Part of body	%	Area	%	Occupation	%
Struck by/falling object	7.2	Hitting to a moving object (except transportation, machinery, mining machine, hand tools)	30.77						
		Falling of an object (others)	19.24	Lower ext	42.31	Workshops	57.69	Maintenance per	73.08
		Dropping of an object held by the employee (except hand tools)	19.23	Upper ext	26.92	Coal handling plant	26.92	Worker	19.23
		Falling of an object on employee from a high level (except transport, repair, maintenance, assembly-disassembly)	15.38	Head	23.08	Surface plants	11.54	Driver	7.69
				Torso	7.69	Opencast mining area	3.85		
		Hitting to a non-moving object	7.69						
		Hitting to an object (others)	7.69						
Manual and mechanical handling	16.7	Hurt waist while carrying, lifting, or putting an object	38.33						
		Compression of body part while carrying, lifting or putting an object	23.33						
		Falling on employee while moving an object	20.00	Torso	46.67	Workshops	46.67	Maintenance per	68.33
		Falling while carrying, lifting, or putting an object	6.67	Upper ext	38.33	Coal handling plant	30	Worker	30
		Others	6.67	Lower ext	15	Opencast mining area	16.67	Driver	1.67
		Falling, hitting, or body part compression during human transport	3.33			Surface plants	6.67		
		Hitting, bumping, compressing of other transportation units	1.67						
Machinery	25	Compression of body part	25.56						
		Hitting of machinery part	21.11						
		Falling on workers of machinery or a part of machinery	16.67	Upper ext	37.78	Workshops	50	Maintenance per	90
		Sinking of burr/chip into extremities	16.67	Head	25.56	Coal handling plant	33.33	Worker	7.78
		Slipping during repair and maintenance at workshops	7.78	Lower ext	24.44	Surface plants	8.89	Driver	2.22
		Hurt waist while moving or lifting of a machine part or as a result of strain	5.56	Torso	12.22	Opencast mining area	7.78		
		Others	5.56						
		Burst of compressed air or hydraulic hose	1.11						
Mining machine	39.2	Hitting of machinery part	22.70						
		Fall from ladder while getting into or getting of the machine	14.18						
		Hurt waist while lifting a part of mining machine or as a result of strain	13.48	Lower ext	34.04	Workshops	54.61	Maintenance per	76.60
		Compression of body part	12.77	Upper ext	26.24	Opencast mining area	40.42	Driver	18.44
		Falling a part of machinery on employee	10.64	Torso	20.57	Coal handling plant	2.84	Worker	4.96
		Falling while working on mining machine	10.64	Head	19.15	Surface plants	2.13		
		Sinking of burr/chip into extremities	10.64						
		Others	4.96						
Hand tools	11.9	Hitting or cutting himself with hand tool	67.44	Upper ext	69.77	Workshops	72.09	Maintenance per	86.05
		Others	16.28	Lower ext	11.63	Coal handling plant	20.93	Worker	11.63
		Falling result of strain while working with hand tools	9.30	Torso	11.62	Surface plants	4.65	Driver	2.32
		Hurt waist while working with hand tools	6.98	Head	6.98	Opencast mining area	2.33		

than 3 lost workdays was three times more likely compared with the opencast mining area. Through a similar evaluation of the remaining variables, the reasons related to accidents for an occupation, area, reason, part of the body and age group can be interpreted.

To generate an equation for calculating the probability of exposure to accidents with greater or less than 3 lost workdays, a binary logistic regression model was created. In this study, for a more detailed risk analysis of the accidents evaluated, it was considered all of the variables. Lost workdays (LDs) were categorized as $LD \leqslant 3$ days and $LD > 3$ days, and in the model, they were coded as 0 for $LD \leqslant 3$ and 1 for $LD > 3$. The chi-square value for the model was 259.526 and the p value was 0.00. The model was statistically significant with a 95% confidence interval ($p < 0.05$). The overall correct classification rate for the model was 86.7% Therefore, it is considered as a successful model. The Nagelkerke R Square analysis shows that approximately 68.5% of the variation in the outcome variable is explained by this logistic model; thus, the explanatory power of the model was considered good. The enter method was used to solve the model, and the SPSS results are shown in Table 5.

The Wald estimates indicate the importance of each variable in the model; the higher the value, the more important the variable (Chan, 2004). From the analyses, the opencast mining area, workshop and coal handling plant for the area variable; hand tools and mining machine for the reason variable; lower extremities for the part of the body variable; as well as the 35–44 age group for the age variable are important risk factors for accidents with greater than 3 lost workdays when the probabilities ($p < 0.05$)

Table 4
Simple binary logistic regression for the primary effects.

	Variables	B	p	Exp(B)	95% CI	
					Lower	Upper
Occupation	Driver		.000			
	Worker	.946	.000	2.575	1.989	3.334
	Maintenance personnel	1.099	.007	3.000	1.348	6.678
Area	Opencast mining area		.000			
	Workshop	.542	.031	1.720	1.051	2.816
	Coal handling plant	.201	.655	1.222	.506	2.949
	Surface plants	1.099	.000	3.000	1.785	5.042
Reason	Hand tools		.000			
	Struck by/falling object	.769	.006	2.158	1.253	3.718
	Manual and mechanical handling	.405	.060	1.500	.984	2.287
	Machinery	1.186	.000	3.273	2.216	4.833
	Mining machine	1.476	.000	4.375	2.030	9.431
Part of body	Torso		.000			
	Head	.858	.000	2.359	1.622	3.431
	Upper extremities	1.453	.000	4.278	2.561	7.146
	Lower extremities	.944	.000	2.571	1.553	4.257
Age	45–54		.000			
	25–34	1.435	.000	4.200	3.034	5.814
	35–44	21.203	.996	1.615E9	.000	.

and Wald values are evaluated together. From the odds ratios evaluation, the possibility of exposure to non-fatal work accidents for a worker is 3.2 times more likely than for drivers. From evaluating the odds ratios and confidence intervals together, the areas with the highest risk are the workshop and coal handling plants. From evaluating all of the variables using the logistic regression model, the probability of an accident injury with greater than 3 lost workdays in the workshop and coal handling plant was 3.19 and 2.96 times more likely than in the opencast mining area, respectively. When the accidents caused by a mining machine were compared with hand tools, mining machines accidents were four times more likely than hand tool accidents. From analyzing the part of the body variable, the lower extremities have the highest risk for injury. If the odds values are close to 0, the investigated variable is an important factor in reducing impact. When the 35–44 age group was compared to the 45–54 age group, the probability of exposure to accidents with less than 3 lost workdays was high. The equation for calculating the probability of exposure to accidents with greater or less than 3 lost workdays is as follows. The numerical values are from the B estimates in Table 5.

$$\begin{aligned} z = {} & 1.168 * Worker + 0.93 * Maintenance\ personnel + 1.161 \\ & * Workshop + 1.088 * Coal\ handling\ plant - 0.107 \\ & * Surface\ plants + 0.706 * Struck\ by/falling\ object + 0.289 \\ & * Manuel\ and\ mechanical\ handling - 0.015 * Machinery \\ & + 1.388 * Mining\ machine - 0.045 * Head + 0.282 \\ & * Upper\ extremities + 0.984 * Lower\ extremities - 23.961 \\ & * (25{-}34) - 1.042 * (35{-}44) \end{aligned}$$

If the maintenance personnel in the 35–44 age group working in the surface plant are exposed to accidents from machinery and the lower extremities are injured, then the z value is 0.75 and $e^{-z} = 0.472$, which generates the probability = 1/(1 + 0.472) = 0.68. This subject will likely lose greater than 3 workdays.

If the maintenance personnel in the 35–44 age group working in the workshop are exposed to accidents from the mining machine and the head is injure, then z value is 2.392 and $e^{-z} = 0.091$, which generates the probability = 1/(1 + 0.091) = 0.916. This subject will likely lose greater than 3 workdays.

If a worker in the 25–34 age group working in the coal handling plant is exposed to an accident from struck by/falling object and the lower extremities is injured, then the z value is -20.015 and $e^{-z} = 492497528.357$, which generates the probability = 1/(1 + 492497528.357) = 0.00. This subject will likely lose less than 3 workdays. Through a similar evaluation of the remaining variables, accidents under various conditions can be interpreted.

5. Conclusion

Non-fatal occupational accidents are frequent in mining, and preventing or decreasing such accidents is only possible through analyses of such accidents and taking precautions given the results of such analyses. When the non-fatal accidents in the Western Lignite Corporation (GLI) of Turkish Coal Enterprises (TKI) were

Table 5
Estimates from the logistic regression model.

	B	SE	Wald	Sig.	Exp(B)	95% CI	
						Lower	Upper
Driver			3.421	.181			
Worker	1.168	.700	2.786	.095	3.215	.816	12.672
Maintenance personnel	.930	.549	2.869	.090	2.535	.864	7.437
Opencast mining area			9.558	.023			
Workshop	1.161	.464	6.255	.012	3.192	1.285	7.927
Coal handling plant	1.088	.553	3.864	.049	2.967	1.003	8.776
Surface plants	−.107	.673	.025	.873	.898	.240	3.357
Hand tools			11.522	.021			
Struck by/falling object	.706	.768	.845	.358	2.025	.450	9.119
Manual and mechanical handling	.289	.529	.299	.585	1.335	.473	3.767
Machinery	−.015	.500	.001	.976	.985	.370	2.626
Mining machine	1.388	.491	7.999	.005	4.006	1.531	10.479
Torso			4.899	.179			
Head	−.045	.564	.006	.937	.956	.317	2.888
Upper extremities	.282	.405	.487	.485	1.326	.600	2.930
Lower extremities	.984	.502	3.846	.050	2.676	1.001	7.156
45–54			5.155	.076			
25–34	−23.961	5208.164	.000	.996	.000	.000	.
35–44	−1.042	.459	5.155	.023	.353	.143	.867

evaluated using a logistic regression analysis method, it was observed that the job groups with the highest probability of exposure to accidents with greater than 3 lost workdays from non-fatal injuries were maintenance personnel and workers. Additionally, employees were most exposed to accidents caused by mining machines. The workshop area has the highest risk of exposure to non-fatal injuries with greater than 3 lost workdays. The part of the body variables with the highest risk were the upper and lower extremities and the age group with the highest probability of exposure to accidents with greater than 3 lost workdays is the 25–34 age group. From evaluating the significant parameters from the analyses together, the maintenance personnel working in the workshop area have the highest probability of exposure to accidents with greater than 3 lost workdays, which affect lower and upper extremities. According to these results, the equipment protecting the lower and upper extremities can be effective in decreasing non-fatal work accidents. Moreover, in the training related to work accidents, the occupational job groups must be considered and educated in the possible risks. This education should include ergonomic hand carrying, careful use of hand tools, working at high, and importance of using personal protective equipment. Within the scope of this study, the logistic regression prediction model was developed to predict the outcome for a new subject. Logistic regression models are flexible and suitable for data that can be grouped categorically. Therefore, if the factors considered are changed, the logistic model will change and, thus, provide valuable information to researchers. When we have a new subject, we can use the logistic model to predict the probability of accidents with greater or less than 3 lost workdays.

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