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Predictors of Occupational Injuries at Continuous Miner Worksite: An Epidemiological Study

Amrites Senapati and Ashis Bhattacherjee

Department of Mining Engineering, Indian Institute of Technology, Kharagpur, India

Corresponding author's Email: ashisb2006@gmail.com

Author Note: Mr. Amrites Senapati is a research scholar of the Department of Mining Engineering and is working in the field of mine safety analytics. Dr. Ashis Bhattacherjee is a Professor in the Department of Mining Engineering and is working in the field of occupational health and safety, injury epidemiology and operations research since last 30 years. Authors are thankful to the management of case study mines for their kind co-operation.

Abstract: Occupational injuries have severe consequences for workers and society. Several past studies have shown that all individuals do not have an equal liability to occupational injuries; and individuals have differential liability to injuries due to different occupational and individual characteristics. The focus of this paper is to study the association between some of the occupational and individual characteristics with injuries occurred at a continuous miner worksite. The data used for this study is collected from a case study mine located in the central part of India. A questionnaire based case-control study design is adopted for data collection. For each case (injured), two controls (non-injured) were matched based on matching criteria age (± 5 years) and job description. This case-control study compared 43 male workers with injuries during the previous two-year period with 86 matched controls without injury during the previous five years. A standardized questionnaire was completed by the trained personnel through face-to-face interview for 129 workers (43 cases and 86 controls). In this study, nine factors were considered including personal factors as well as occupational hazards. The Mantel-Haenszel test was used to check the association of nine factors with the injury occurrences. The results revealed that seven out of the nine factors were significantly associated with the injuries. Odds ratio was also computed for all the nine factors considered in this study. The following seven factors were found to have significant odds ratio: no-formal education, big family size, presence of disease, poor safety awareness of worker, exposure to working condition-related hazards, exposure to strata control-related hazards, and exposure to shuttle car-related hazards. Inferences drawn in this study can help the mine management to improve the safety performance of the workforce. Pertinent intervention strategies by management will help workers to reduce work-related diseases and to increase safety awareness among them.

Keywords: Risk factors, Continuous miner technology, case-control study, Mantel-Haenszel test

1. Introduction

Ever increasing demand for minerals has thrown greater emphasis on mechanization, introduction of new mining techniques and tools which in turn will result in increased hazard potential. According to Galvin (1998), a new technology produces more output with lesser people, but introduces different types of occupational injuries. Engineering solutions to injuries are by themselves insufficient in the prevention of injuries in the wake of increased mechanization and automation in the mining industry. One such highly mechanized technology is continuous miner technology. In the underground coal mining sector of India, continuous miner technology is gaining wider acceptance since its first deployment in 2002 at Chirimiri Anjan Hill Mine of South Eastern Coalfields Limited. As the continuous miner worksite is an active production area, there are a number of prevalent occupational hazards which can lead to accidents/injuries (Burgess-Limerick and Steiner, 2006; Bartels et al. 2009).

Different studies indicated that behavioral factors along with other personal factors have a major role to play in underground coal mine injuries (Bhattacherjee et al., 2013; Kunar et al., 2010; Paul and Maiti, 2007). Peake and Ritchie (1994) suggested in their study that while human behavior plays a major role in many injuries, mechanical and environmental failures also play a significant causative role and consequently must be addressed if any meaningful and long-term reduction in mine injuries is to be achieved. But the role of aforementioned personal and occupational factors were not studied in depth for the injuries occurring at continuous miner worksites. This kind of knowledge is important because it will help to design the preventive measures concerning these factors.

Therefore, the present study is aimed at assessing the relationships of nine such individual and occupational factors with the incidence of occupational injuries at the continuous miner worksite from a mine of central part of India by using statistical approach for a matched case-control study.

2. Study Design

The design, which was used in this study, was a case-control study. The survey was conducted on 129 underground mine workers working at a continuous miner (CM) section of a mine. For each case, two controls were matched based on matching criteria. The cases were the underground workers who suffered injury at least once during the previous two years period of 2015-2016. The injured miners were identified from the injury registry of 2015 and 2016 which was maintained by the safety department of the mine. During the two years period (2015-2016), the CM section registered 43 injured cases. For each case, two controls matched on age (± 5 years) and job description were randomly selected from the workers who did not face any injury during the past five years period. As a result, a total 43 case-control pairs (1:2 matched pairs) is considered for this study. The protocol of this study included the following: (i) a request of participation of the mine management, and (ii) a questionnaire-based survey. A questionnaire, completed by the personnel interviews, included many factors among which educational status, family size, presence of disease, worker's view about management and supervision, supervisor's view about safety awareness of worker, working condition-related hazards, strata control-related hazards, continuous miner-related hazards, shuttle car-related hazards, and occupational injuries were analyzed and summarized for the purpose of this paper. The questionnaires were filled up by conducting face-to-face interviews with each worker separately. Each of the interviews required a time span of 15-20 minutes.

All of the variables were divided in two categories according to their descriptions. To capture the worker's view about management and supervision and supervisor's view about safety awareness of a worker, ten items for each factor (negatively formulated) were used. Responses were scored (yes=3, cannot say=2 and no =1) and summarized for total score. For categorization, 90th percentile of the total score of the non-injury group was used as a threshold value. Variables working condition-related hazards, strata control-related hazards, continuous miner-related hazards, and shuttle car-related hazards were captured through eight, five, fourteen, and twelve items respectively. Workers were divided into two categories: exposed (= 1) and not-exposed (= 0) to various hazards based on their exposer to at least one item. The occupational injury was the dependent variable with value 1 = Yes and 0 = No. The variable family size was also divided into two categories: small family (number of members < 6) and big family (number of members ≥ 6). All other factors were also divided into two categories. All the factors and their categorization criteria are presented in Table 1.

Table 1. Categorization of the factors

Factors	No of categories	Coding Scheme for Statistical Model
Occupational injury	2	0=No ,1=Yes
Education	2	0= Formal education, 1=No formal education
Family size	2	0=Small (Members < 6), 1= Big (Members ≥ 6)
Presence of disease	2	0=No Disease, 1= Some disease
Management and supervision: worker's view	2	0= Good (score <22), 1= Poor (score ≥22)
Safety awareness of worker: supervisor's view	2	0= Good (score <18), 1= Poor (score ≥18)
Working condition-related hazards	2	0= Not-exposed (exposure < 1), 1=Exposed (exposure ≥ 1)
Strata control-related hazards	2	0= Not-exposed (exposure < 1), 1=Exposed (exposure ≥ 1)
Continuous miner-related hazards	2	0= Not-exposed (exposure < 1), 1=Exposed (exposure ≥ 1)
Shuttle car-related hazards	2	0= Not-exposed (exposure < 1), 1=Exposed (exposure ≥ 1)

To assess the effect of various factors individually on occupational injury, statistical analyses were carried out. The relationship between various factors and injury were examined via the Mantel-Haenszel test. The odds of injury for the presence of the various risk factors considered in this study were also calculated through the same test. The IBM SPSS (Version-20) and Stata package were used for the statistical analyses.

3. Case Study

A case study mine from central part of India was selected for the data collection. The mine is a large mechanized underground coal mine. The development of the mine started in early 1990s. The mine has five extractable coal seams. Continuous miner technology was introduced from 2012. Continuous miner technology has been successfully implemented in the mine with enhanced production and productivity. Besides the continuous miner technology, production is also achieved through the application of side discharge load haul dumpers (LHD). The average production from the continuous miner section is 1420 tonnes per day and the total production from the mine is 2800 tonnes per day. The total number of workers in the mine is 1252, which includes 291 workers employed at the continuous miner section.

3.1 Results

A total number of 283 injuries, including 38 serious injuries and 86 reportable injuries, was experienced from the mine during the last 2-year period. These injuries were experienced from continuous miner sections (43) as well as LHD sections (240). The Mantel-Haenszel test were performed based on the survey data of 129 mine workers to determine whether there was any significant association between hypothesized risk factors and an injury which was experienced from the continuous miner section. The test revealed that there were seven significant risk factors: educational level, family size, presence of disease, supervisor's view about safety awareness of worker, working condition-related hazards, strata control-related hazards, and shuttle car-related hazards. There was no significant association between injuries and worker's view about management and supervision, and continuous miner-related hazards. Results of the Mantel-Haenszel test are presented in Table 2.

Table 2. Characteristics (%) of the cases and of the controls (43 pairs) based on causal factors

Risk Factor	Cases (%) (43 subjects)	Controls (%) (86 subjects)	Mantel-Haenszel test statistic Value	P-value
No-formal education	41.9	26.7	6.02*	0.0142
Big family size	69.8	39.5	10.24**	0.0014
Presence of disease	37.2	16.3	6.23*	0.0126
Poor management and supervision	74.4	77.9	0.18	0.6714
Poor safety awareness of worker	55.8	36.0	4.52*	0.0336
Exposure to working condition-related hazards	81.4	62.8	5.33*	0.0205
Exposure to strata control-related hazards	88.4	73.3	3.67*	0.0493
Exposer to continuous miner-related hazards	44.2	27.9	2.97	0.0848
Exposer to shuttle car-related hazards	88.4	48.8	16.06***	0.0001

Level of Significance: *(p<0.05), **(p<0.01) and ***(p<0.001)

To assess the effect of various factors on occupational injuries, the crude odds ratios and their 95% confidence intervals (CI) were also computed for the paired data. The odds ratio calculated through Mantel-Haenszel test provides a measure of the risk of experiencing an injury among the workers with the risk factor to the risk of experiencing an injury among the workers without the risk factor.

The odds ratios along with their 95% confidence interval for the various risk factors are given in Table 3. The odds ratio and 95% CI of statistically significant factors were: no-formal education (OR: 2.9; 95% CI 1.19 – 7.07), big family size (OR: 3.2; 95% CI 1.50 – 6.67), presence of disease (OR: 2.8; 95% CI 1.20 – 6.52), poor safety awareness of worker (OR: 2.2; 95% CI 1.04 –4.70), exposure to working condition-related hazards (OR: 3.3; 95% CI 1.12 – 9.58), exposure to strata

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control-related hazards (OR: 2.6; 95% CI 1.05 – 7.32), and exposure to shuttle car-related hazards (OR: 5.9; 95% CI 2.19 – 15.63).

Table 3. Association of different causal factors with occupational injury: crude odds ratio and 95% CI

Risk Factor	Crude Odds ratio	95% Confidence interval
No-formal education	2.9*	1.19 – 7.07
Big family size (Members ≥ 6)	3.2**	1.50 – 6.67
Presence of disease	2.8*	1.20 – 6.52
Poor management and supervision (score ≥ 22)	0.8	0.36 – 1.94
Poor safety awareness of worker (score ≥ 18)	2.2*	1.04 –4.70
Exposure to working condition-related hazards (exposure ≥ 1)	3.3*	1.12 – 9.58
Exposure to strata control-related hazards (exposure ≥ 1)	2.6*	1.05 – 7.32
Exposer to continuous miner-related hazards (exposure ≥ 1)	1.9	0.9 – 4.15
Exposer to shuttle car-related hazards (exposure ≥ 1)	5.9***	2.19 – 15.63

Level of Significance: *(p<0.05), **(p <0.01) and ***(p <0.001)

4. Conclusions

Out of nine risk factors that were initially assumed to be affecting the mine worker's experiencing an injury, seven factors were found to have significant association with it. Based on the assessment of odds ratio, the statistically significant risk factors were education level, family size, presence of disease, supervisor's view about safety awareness of worker, working condition-related hazards, strata control-related hazards, and shuttle car-related hazards. Pertinent intervention strategies by management will help workers to reduce occupational diseases and to increase safety awareness among them. This information would help the mine management to focus on the problem areas and come up with prevention programs which is more pertinent to the continuous miner worksite.

In this paper, the effects of each variables are considered individually through Mantel-Haenszel test and crude odds ratio, neither of which can assess the combined effects of all the factors to the occurrence of an injury. Multivariate analysis is needed to study the combined effect of risk factors in an injury.

5. References

Stata Corporation (2005), Stata Statistical Software: release 9.0. College Station, TX, Stata Corporation.

Statistical Package for the Social Sciences (IBM-SPSS 20), Inc. Chicago IL (2013): SPSS Reference Guide.

Burgess-Limerick, R. and Steiner L., (2006), "Injuries Associated with Continuous Miners, Shuttle Cars, Load-haul-dump and Personnel Transport in New South Wales Underground Coal Mines", Mining Technology, Vol 115, No. 4, pp. 160-168.

Bartels, J.R., Gallagher, S., and Ambrose, D.H. (2009), "Continuous mining: A pilot study of the role of visual attention locations and work position in underground coal mines", Professional Safety, 54(8), pp 28-35.

Bhattacherjee, A., Kunar, B. M., Baumann, M., and Chau N., (2013), "The Role of Occupational Activities and Work Environment in Occupational Injury and Interplay of Personal Factors in Various Age Groups among Indian and French Coalminers", International Journal of Occupational Medicine and Environmental Health, Vol. 26 (6), pp. 1-20

Galvin J (1998). Cooking the Books: Lies, Lies & Damned Statistics. Australian Mining Monthly. 32: Perth: Aspermont Limited.

Kunar, B.M., Bhattacherjee, A. and Chau N., (2010), "A Matched Case-Control Study of Occupational Injury of Underground Coal Mine Workers", The Journal of South African Institute of Mining and Metallurgy, Vol. 110, pp. 1-9.

Paul, P. S., and Maiti, J., (2007), "The role of behavioral factors on safety management in underground mines", Safety Science, 45(4), 449-471

Peake A.V., and Ritchie, A.J., (1994), "Establish the primary causes of accidents in mines other than gold, coal and platinum" CSIR Project report, CSIR, Mining Technology, South Africa.