Transaction Paper

A matched case-control study of occupational injury in underground coalmine workers

by B.M. Kunar*, A. Bhattacherjee†, and N. Chau‡§

Synopsis

It is well known that job-related hazards and individual factors influence occupational injuries. However, research involving coal miners has been limited. This case-control study assessed the relationships of job-related hazards and individual/life style factors with injuries among underground coal miners. It compared 245 cases with at least one injury during the previous two-year period with 245 matched controls with no injury. The data were gathered via personal interview and analysed using the conditional logistic model. The significant risk factors were materials handling (adjusted OR 5.15), poor environmental/working conditions (2.63), geological/strata control-related hazards (2.35), lack of formal education (3.00), sleep disorders (1.86), alcohol consumption (2.32), disease (2.23), having a large family (5.40), and risk-taking behaviour (9.40). Machine-related hazards, sleep disorders and alcohol consumption primarily affected workers aged less than 45 years; whereas, environment/working condition-related hazards, presence of disease, smoking, risk-taking behaviour and large family size were more likely among workers aged 45 or over.

Keywords: Occupational injuries, sleep disorders, job hazards, alcohol, coal miners

Introduction

Accidents and injuries related to work are a major occupational health problem in most industrialized countries.[1] Around 270 million work-related injuries, 2 million work-related fatalities and 160 million new cases of occupational disease occur each year in the world from a total workforce of 2.7 billion people.[2] The accident and ill-health record of the mining sector compares poorly to that of other economic sectors such as manufacturing, construction and railways[3]. For example, a study based on fatality information during the 16-year period from 1980 to 1995 reported that the industries in the United States with the highest death rates per 100 000 workers were mining (30.3), agriculture/forestry/fishing (20.1), and construction (15.2)[4]. Moreover, overall data for the USA mining industry for the year 2004 revealed that coalmining had a higher fatal and non-fatal injury rate than any other mining sector. A National Institute of Occupational Safety and Health (NIOSH) analysis showed that by the age of 51 years, about 90% of coal miners and 49% of metal/non-metal miners had a hearing impairment[5].

Due to the importance of mining to employment and the economy in South Africa, there is significant value for the local mining industry by addressing health and safety issues systematically. Over the years the safety performance of South African mines has improved, but not at the same rate as in other major mining countries such as Australia, Canada and the USA[3]. It appears that South African miners are 4–5 times more likely than their Australian counterparts to lose their lives in mine accidents[3].

The Indian coal mining industry has undergone huge technological development over recent years. The shift of technology in the last decade, from conventional underground mining to mechanized opencast and underground mining and a reduction in manpower through mechanization, have reduced the number of injuries. However, it is important to recognize that much remains to be accomplished to achieve the goal of totally safe mines. The annual rate of fatal and serious injuries (per 1 000 workers) did not decrease during the 10-year period 1997–2006 in Indian coal mines (Figure 1)[6].

* *Department of Mining Engineering, Indian School of Mines, Dhanbad, India.*

† *Department of Mining Engineering, Indian Institute of Technology, Kharagpur, India.*

‡ *INSERM, Paris, France.*

§ *University of Paris-Sud and University Paris Descartes, Paris, France.*

 SA ISSN 0038–223X/3.00 + 0.00. Paper received Jun. 2008; revised paper received Sep. 2009.

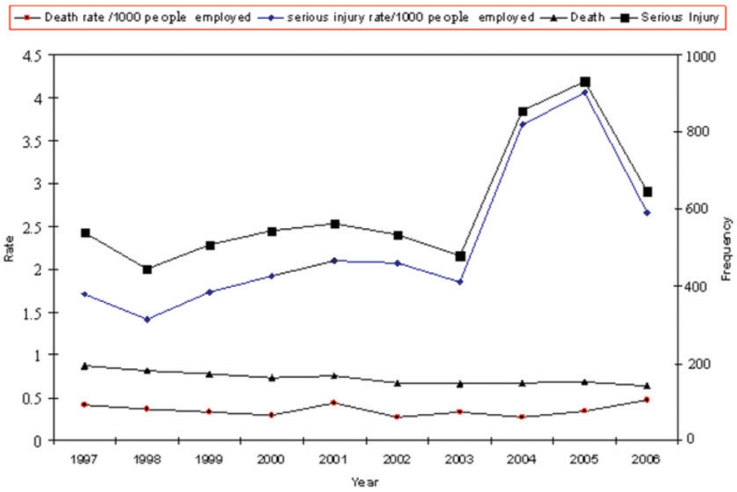

Figure 1—Incidence rate of fatal and serious injuries in Indian coalmines during 1997–2006

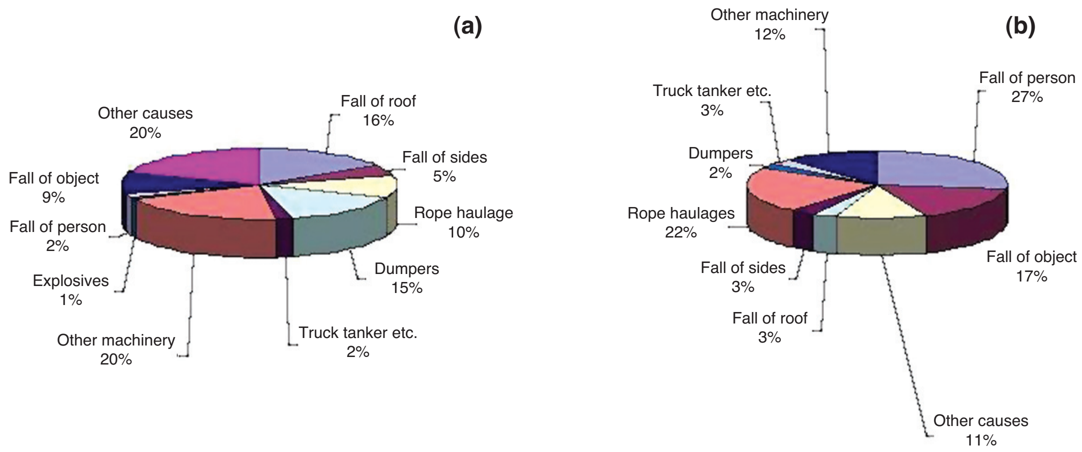

Figure 2—Distribution of cause of fatal (a) and serious injuries (b) in Indian coalmines in 2006

Across the globe, laws regulating the health and safety of workers are increasing, including requirements for risk assessment and risk management. The management of risk is present in almost all industries, but is particularly important for mining because it is one of the most hazardous industries in the world[7]. In order to address issues of risk management, the South African mining industry established a Hazard Identification and Risk Assessment (HIRA) program[8]. The HIRA is considered to be an ongoing process of systematic identification and documentation of significant risks involving not only the industry but also manufacturers and suppliers. Outcomes of the HIRA process are inputs for the risk treatment process, itself part of the broader risk management process. However, the HIRA programme does not address all aspects of risk management. In Indian mines, the Directorate General of Mines Safety (DGMS) has introduced a risk management plan in which the mine management is requested to identify the job and health hazards at workplaces, to estimate the risk associated with them and to take necessary preventive measures.

Injuries pose a significant threat to the health and well-being of workers in coalmines. Consequences of injury include increased absenteeism and use of medical care services, reduced productivity, loss of working time, and disability. A number of job-related hazards as well as socio-economic factors, lifestyle factors and health-related factors have been reported to be associated with the risk of being injured, especially in the mining, railway and construction industries.[9–11] Health researchers found that lifestyle risk factors (smoking habit, regular alcohol consumption, sleep disorders and sedentary lifestyle) commonly affect health status.[12–14]) Hazards at the workplaces arise from unsafe conditions, which include unguarded machinery and defective or broken tools, poor working environment (slippery floors, poor workplace upkeep, etc.), and unskilled operators. Whatever the source, hazard is part of the mining process and offers challenges to the mining community to research and evaluate new strategies.

Every day, miners are exposed to several job-related hazards such as heat, humidity, noise, dust, inadequate ventilation, and slippery floors, all of which certainly impose additional stresses. Some studies have shown the role of work environment, working conditions, job stress and job dissatisfaction in injuries.[10,14,15] Analysis of fatal accidents in Indian coal mines in 2006 revealed that certain machines such as shovels, dozers, drilling machines, load haul dumpers and side discharge loaders are the leading cause (19.5%), followed by roof falls (15.9%) and dumpers (14.6%) (Figure 2a[6]. Analysis of serious injuries found the major causes to be: people slipping and falling (26.4%), rope haulage (22.4%), falling objects (16.8%) and roof falls (3.7%)[16] (Figure 2b)[6]. Injuries due to slip and fall of persons are a major safety problem in Indian coalmines, and require proper attention.[17]

Some research studies have shown that living conditions and lifestyle factors such as smoking, alcohol use, sleep disorders, disease and disabilities are associated with workplace injury as they alter workers' physical and mental abilities, particularly in task performance and in awareness of job-related hazards.[18–21] The presence of diseases among the workers are important issues in the mining industry. The ILO estimated that the total number of occupational disease-related deaths in South Africa was 8229 in 2001[3]. It is not clear how many of those deaths were associated with mining, but the available data suggest that former and current miners bear a huge burden of occupational disease. According to Hermanus (2007), statistics on occupational health impacts are unavailable, but noise and respirable dust levels are known to be high in mines.[3] It is necessary to investigate the individual/lifestyle factors which, along with job-related hazards, are associated with injury. Furthermore, in Indian coalmines the lengthening of working life is likely to result in more people working into older age and consequently at increased risk of various diseases and disabilities well known to be risk factors for injury.[15] Younger people are more likely to suffer occupational injury because of lack of knowledge.[20] Therefore, the roles of job-related hazards and individual/lifestyle factors in injury may differ between various age groups. A better understanding of these patterns will help mine managements develop effective injury prevention programmes.

The present study assessed the relationships of job-related hazards, educational level, current smoking, sleep disorders, regular alcohol consumption, presence of disease, risk-taking behaviour, and family size with occupational injury for the total subject population and for subjects aged under 45 years and those aged 45 years or more. These age groups were chosen because the prevalence of disability increases from the age 40–50[20] and also to provide sufficient subjects.

Materials and methods

Epidemiologic investigation is used as a tool for risk analysis and is very popular among those addressing health and safety issues of workers. The present survey was a case-control study conducted in 2005 in workers from two underground coalmines located in the southern part of India. Both the mines belonged to the same coal company and they employed a total of 2 376 miners during the period 2003–2004. The method of coal extraction was mainly bord and pillar technique. Face working at both mines was mainly semi-mechanized, comprising drilling, blasting, load-haul-dumper and side-discharge-dumper loading, and chain conveyor/mine car transporting. The average total annual production from the mines was 400 000 tons. Only male

Table I

Characteristics of the two coalmines

	Mine 1	Mine 2
First year of operation	1 974	1 976
Total number of workers	1 304	1 072
Production (million tonne/year)	0.43	0.39
Seam depth (range in metres)	184–291	276–330
Seam thickness (range in metres)	4–11	1.5–11
Number of seams worked	2	3
Gradient of the seam	5–70	8–110
Immediate roof	Shale and sandstone	Shale and sandstone
Mining method	Board and pillar	Board and pillar
Face mechanization	Load haul dumper, side discharge dumper, and chain conveyor	Load haul dumper, side discharge dumper, and chain conveyor
Out-by coal transport	Belt conveyor	Belt conveyor
Roof support	Props, girders, and roof bolts	Props, girders, and roof bolts
Rate of emission of inflammable gas inside the mine	Inflammable gas <0.1% and emission of gas <1 m^3/tonne	Inflammable gas <0.1% and emission of gas <1 m^3/tonne
Number of injuries during 2003–2004		
Fatal	2	0
Serious	29	7
Reportable	86	37
Minor	60	41
Annual frequency rate of injuries per 1 000 persons		
Fatal	0.76	0
Serious	11.1	3.2
Reportable	32.9	17.2
Minor	23.0	19.1

workers were employed in the mines; half of them were illiterate. The working week was six 8-hour days. The characteristics of these two mines are shown in Table I. Mine 1 experienced more fatal, serious and reportable injuries than Mine 2. Total numbers of fatal, serious, reportable and minor injuries in the two mines during the 2-year period (2003–2004) were 2, 36, 123 and 101 respectively. In this study, severity of injuries was defined as per the classification of Directorate General of Mines Safety (DGMS).[17] According to the DGMS, fatal injury results in death of one or more persons. Serious injury is defined as an injury that involves the permanent loss of any part of the body or the permanent loss of sight or hearing or any permanent physical incapacity or the fracture of any bone or joint. Reportable injury is defined as any injury other than a serious bodily injury that involves the enforced absence of the injured person from work for a period of 72 hours or more. Minor injury means any injury which results in enforced absence for a period exceeding 24 hours and less than 72 hours.

Subjects

The cases were the subjects who experienced at least one injury during the 2-year period 2003–2004 (annual incidence rate of injury 5.5%). All the injured people from the mines participated in the study. Of the total of 245 subjects with at least one injury, eight had two or more injuries, and there were nine lost cases (two fatal injuries and seven retirements). For each case, two controls were planned to be randomly selected from subjects who had no injuries over the previous 5 years and were matched for age and job. However, although two controls were available for 85 cases, only one was available for the other 160 cases, giving a total of 330 controls.

Study design

The survey was a matched case-control study conducted on 245 case-control pairs (two controls for 85 cases). The mine management introduced the interview team to the workers. A standardized questionnaire was completed by a trained person during a face-to-face interview; questions included age, experience, job occupation, sleep disorders, regular consumption of alcohol, smoking habit (non-smoker/current smoker/ex-smoker), total number of dependants, job-related hazards, and occupational injuries during the previous two-year period (2003–2004). Concerning lifestyle factors, sleep disorders were recorded as 'Daily hours of sleep' (available responses: 'Less than 6 hours' and '6 hours or more').

In earlier studies by the present authors, excess alcohol consumption was defined by at least two positive responses to the four items of the DETA-CAGE questionnaire: (i) consumption considered excessive by the subject himself/herself, (ii) consumption considered excessive by people around the subject, (iii) wish to reduce the consumption, and (iv) consumption on waking.[13] However, as the risk associated with regular alcohol consumption is high, it was not thought appropriate to focus only on workers whose alcohol use was excessive. As a result, alcohol consumption was recorded in terms of response to 'Do you consume alcohol regularly' ('yes/no').

Smoking habit was recorded as 'Do you have any smoking habit' ('non-smoker/current smoker/ex-smoker') because our earlier studies had revealed that the number of cigarettes consumed per day and the total tobacco consumption during the whole life (number of pack-years) displayed similar results to 'being a current/ex-smoker'.

Eight categories of job hazard were studied, each assessed by one or more items: I. hand tool-related, one item; II. material handling-related, one item; III. environmental hazards, eight items; IV. geological and strata control hazards, five items; V. machine-related hazards, five items. VI. electrical equipment related-hazards, three items; VII. blasting-related hazards, 2 items; and VIII. haulage-related hazards, two items. The interview team asked workers to indicate whether they had been exposed to the hazard(s) until the occurrence of the last occupational injury.

Statistical analysis

All variables were divided into two categories according to their descriptions. Subject age was categorized as Under 45 years and 45 years or more. Alcohol consumption, smoking habit, and overtime work were categorized as Yes=1 and No=0. Sleep disorder was categorized as Less than 6 hours=1, and 6 hours or more=0. Job hazards were categorized as Exposed=1 and Not-exposed=0. The risk-taking behaviour score was computed by summing the score of individual items; then the 90th percentile value of the score of the controls (equal to 12) was used as a threshold value to define the group at risk. For educational level, our study focused on no formal education (that is, those subjects who were not able to read and write). Large family size was defined as five or more dependants. To assess the effect of various factors on occupational injuries, the crude odds ratios and their 95% confidence intervals (CI) were computed using the Mantel-Haenszel test for paired data. The adjusted odds ratios were then calculated via the conditional logistic regression model for paired data.

Logistic regression is commonly used in the analysis of case-control studies for the simultaneous estimation of the effects of multiple covariates on the odds of the response variable. As our study is a pair-wise matching case-control study, the conditional logistic regression model was well suited to it. Conditional logistic regression differs from unconditional logistic regression in that data are divided into groups, and within each group the observed probability of positive outcome (injury, in the present study) is predetermined due to data construction (matched case-control). The explanatory variables included in the model were: educational level, smoking habit, sleep disorders, regular consumption of alcohol, disease, family size and various job-related hazards. The outcome variable considered in the model was the occurrence of injury. Adjusted odds ratios were computed considering all the explanatory variables in the model. The analyses were first performed for all subjects, then separately for the two age groups (under 45 years, and over 45 years or more), using the Stata package.[22]

Results

Participants ranged in age from 18 to 60 years, with means of

Table II

Characteristics of the injured workers: %

	Subjects aged <45 yrs (116 cases)	Subjects aged ≥45 yrs (129 cases)	Total (245 cases)	*p*-value[a]
Mean age (SD) yr	38.4 (4.6)	48.0 (4.1)	43.3 (6.8)	
Laborer	40.4	23.2	31.1	0.013
General worker	25.0	23.3	24.3	
Driller	4.3	17.8	11.3	
Multi-skilled group	7.8	6.2	6.9	
Fitter	4.3	2.3	3.5	
Support-man	4.3	3.1	3.4	
Conveyor operator	2.6	3.1	2.8	
Shot firer	0.9	3.9	2.6	
Tyndal	0.9	3.1	2.3	
Trammer	0.9	3.1	1.7	
Other	8.6	10.9	10.0	
Type of injury				
Slip and fall	32.8	26.4	29.3	0.171
Fall of object	23.3	29.5	26.6	0.169
Collision with object	26.7	17.1	21.6	0.046
Other	17.2	27.1	10.3	0.044
Type of lesion				
Wound	36.6	33.3	34.6	0.132
Contusion	23.3	28.7	26.0	
Fracture	25.8	17.1	21.2	
Sprain and luxation	13.8	15.5	15.0	
Other	0.9	5.4	3.2	
Localization of lesion				
Finger	32.8	21.7	27.0	0.001
Leg	23.3	23.1	23.3	
Knee	13.8	7.8	10.7	
Eye	6.9	12.4	9.7	
Elbow	2.6	14.0	8.7	
Back	6.9	7.0	6.8	
Chest	8.6	1.6	4.9	
Ankle	3.4	3.9	3.9	
Other	1.7	8.5	5.0	

[a]Comparison between the distribution of the variable for the three groups.
In total there were 262 injuries in the mines. There were 245 workers with at least one injury who participated in this study; 8 of them had two or more injuries; and 9 cases were lost (2 fatal injuries and 7 retirements). The last injury was considered for the subjects with two injuries or more.

43.3 (SD 6.8) years for cases and 43.8 (SD 6.3) years for controls. The characteristics of the injured workers are shown in Table II. Among them, 47.4% were aged less than 45 years and 52.6% were 45 or over. Labourers and general workers represented around 65% of under 45-year-olds and around 46% of the over 45 years group. Type of injury 'collision with objects' was more common among subjects aged under 45 years than among their older colleagues (p=0.046). Types of lesion were similar between the two age groups. Lesions involving finger, leg and knee accounted for 70% of subjects aged less than 45 years; whereas, finger, leg, eye and elbow accounted for 71% of subjects aged 45 or more.

Table III shows the distribution of disease in the workers under study. Of the total population, 15.3% had diseases and the remaining 84.7% were disease free. Musculoskeletal disorders, cardiovascular diseases, respiratory diseases, vision disorders, and other conditions each affected between 4% and 10% of miners.

Table IV shows that for all ages combined, significant crude odds ratios (OR) were found for all factors considered except current smoker, electrical equipment-related hazards, haulage-related hazards and blasting-related hazards. Significantly higher adjusted odds ratios (ORa) were found for no formal education (3.00), sleep disorders (1.86), regular consumption of alcohol (2.32), presence of disease (2.23), large family size (5.40), risk-taking behaviour

Table III

Distribution of diseases

	Disease present (%)	Disease free (%)
Total study population (2 376 subjects)	15.3	84.7
Case group (245 subjects)		
Presence of diseases	53.1	46.9
Cardiovascular diseases	16.7	
Vision disorders	13.5	
Musculoskeletal disorders	9.0	
Respiratory diseases	7.5	
Other diseases	6.4	
Control group (330 subjects)		
Presence of diseases	29.4	70.6
Cardiovascular diseases	8.6	
Vision disorders	6.6	
Musculoskeletal disorders	3.7	
Respiratory diseases	4.5	
Other diseases	5.8	

Table IV

Relationships of job hazards and individual characteristics with occupational injury (245 pairs): %, crude odds ratios (OR), adjusted odds ratios (ORa) and 95% confidence interval (CI)

	Cases (%)	Controls (%)	OR and 95% CI		ORa and 95% CI	
No formal education	62.9	50.9	1.95‡	1.31–2.91	3.00†	1.38–6.84
Current smoker	21.2	16.1	1.47	0.95–2.25	1.79	0.79–4.05
Sleep disorders (<6 h)	50.2	28.5	2.30‡	1.69–3.14	1.86*	1.01–3.45
Regular consumption of alcohol	67.8	41.5	2.52‡	1.82–3.50	2.32†	1.24–4.36
Presence of disease	53.1	29.4	2.94‡	2.01–4.29	2.23†	1.16–4.26
Risk-taking behaviour	59.6	11.2	8.66‡	5.54–13.5	9.40‡	2.63–9.07
Large family (≥5 dependants)	53.9	22.1	4.44‡	2.88–6.83	5.40‡	2.39–9.27
Job-related hazards						
Hand tool-related hazards	30.2	12.4	3.00‡	1.94–4.65	1.24	0.52–2.96
Material handling-related hazards	51.4	19.7	4.12‡	2.83–5.99	5.15‡	2.36–11.2
Machine-related hazards	48.2	24.5	2.50‡	1.79–3.49	1.19	0.90–3.12
Environment/working condition-related hazards	70.6	57.0	1.67†	1.19–2.34	2.63†	1.53–4.69
Geological/strata control-related hazards	62.4	41.8	2.21‡	1.60–3.06	2.35†	1.53–4.69
Electrical equipment-related hazards	24.5	19.1	1.25	0.82–1.90	0.64	0.23–1.79
Haulage-related hazards	20.8	18.2	1.10	0.72–1.68	0.78	0.23–2.67
Blasting-related hazards	22.9	18.8	1.14	0.73–1.76	1.13	0.33–3.90

*$p < 0.05$
†$p < 0.01$
‡$p < 0.001$
There were 245 pairs: 160 pairs matching 1 control for every case, and 85 pairs matching 2 controls for every case.

(9.40), material handling-related hazards (5.15), environment/working condition-related hazards (2.63), and geological/strata control-related hazards (2.35).

Table V reveals that the risk patterns differed between the age groups. Indeed, presence of disease and smoking were significant risk factors among the subjects aged greater than 45 years (ORa 3.12 and 4.27, respectively) while sleep disorders and alcohol consumption were risk factors for the subjects aged less than 45 years (ORa 3.17 and 2.99, respectively). Risk-taking behaviour and larger family size were significant in both age groups but the risks associated were greater for subjects aged greater than 45 years. No formal education had similar ORa for the two age groups. For job-related hazards, the risks associated were similar for the two age groups, except that machine-related hazards concerned more subjects aged less than 45 years, and environment/working condition-related hazards concerned more of the older group.

Discussion

This matched case-control study demonstrated that personal factors and job-related hazards made important contributions to occupational injury and their roles differed between the miners aged less than 45 years and those aged greater than 45 years. Presence of disease and smoking were significant among the older miners. Sleep disorders and regular consumption alcohol were significant among individuals under 45. The two age groups of controls had similar frequencies of: presence of disease (28.8% among the subjects aged less than 45 years vs. 29.9% among the others); regular alcohol consumption (35.9% vs. 46.3%); current smoking (17.5% vs. 14.7%); risk-taking behaviour (11.1% vs. 11.3%); and large family (22.5% vs. 21.5%). This would suggest that these factors do not differ between the two age groups among all the miners of the company, but the risks they produce greatly differ between those age groups.

The effects of risk-taking behaviour and having a large family were greater among the subjects aged over 45 years than among the others, whereas no formal education had similar roles in the two age groups. Specifically, the significant risk factors are discussed under the following sub-headings: individual factors and job-related factors.

Individual factors

Significant individual risk factors with high adjusted odds ratio values were: (i) risk-taking behaviour, (ii) large family size, and (iii) no formal education. Risk-taking behaviour was found to be a strong risk factor for injury in the total study population and for both age groups; however, its odds ratio was higher for respondents aged greater than 45 years. This could be explained by older workers being more sure about their activity. They were quite autonomous in taking their own decisions and ignoring the risks associated with specific tasks. Thus, our results suggest that supervisors should aim to increase awareness among all workers, particularly those aged 45 years or over who take risks at work.

Having a large family was found to be associated with a 4-fold higher risk among the workers aged less than 45 years and with a 7-fold higher risk among those aged 45 or more. Discussions with mine management and supervisors revealed that the older workers, who tended to be the ones with large families, were less safe in terms of their mental status at work because they had more commitment and responsibility towards family members. Occupational physicians could help them become more aware of the risks. This study also found that half of the workers had no formal education. They were more likely to commit human errors as they are socially less well prepared to adopt new technologies, undertake job training, and follow safe working procedures.

Sleep disorders were associated with occupational injury for subjects aged less than 45 years, with an adjusted odds

Table V

Relationships of job hazards and individual characteristics with occupational injury among subjects aged under 45 yrs and subjects aged 45 yrs or over: %, crude odds ratios (OR), adjusted odds ratios (ORa) and 95% confidence interval (CI)

	Cases (%)	Controls (%)	OR and 95% CI		ORa and 95% CI	
Subjects aged less than 45 yrs (116 pairs)						
No formal education	59.5	43.8	2.28†	1.27-4.08	3.83*	1.08-13.5
Current smoker	15.5	17.5	0.84	0.42-1.70	0.73	0.19-2.71
Sleep disorders (<6 h)	62.1	32.0	2.51‡	1.64-3.86	3.17*	1.20-8.33
Regular consumption of alcohol	66.4	35.9	2.82‡	1.75-4.53	2.99*	1.02-8.66
Presence of disease	59.6	28.8	3.58‡	2.02-6.35	2.16	0.69-6.74
Risk-taking behaviour	57.8	11.1	7.48‡	4.04-13.8	5.09†	1.58-16.4
Large family (≥5 dependants)	53.4	22.9	4.00‡	2.20-7.26	4.24†	1.28-14.1
Job-related hazards						
Hand tool-related hazards	34.5	11.8	3.42‡	1.82-6.10	1.30	0.30-5.51
Material handling-related hazards	47.4	17.6	3.68‡	2.16-6.28	7.32†	1.96-27.3
Machine-related hazards	48.3	19.6	3.26‡	1.94-5.46	3.34†	1.05-10.6
Environment/working condition-related hazards	70.7	60.8	1.40	0.85-2.32	3.08*	1.00-9.53
Geological/strata control-related hazards	58.6	45.1	1.75*	1.08-2.83	2.80	0.91-8.66
Electrical equipment-related hazards	19.0	19.6	0.90	0.46-1.77	0.74	0.13-4.19
Haulage-related hazards	15.5	17.0	0.82	0.41-1.63	0.79	0.07-8.55
Blasting-related hazards	19.8	19.0	1.01	0.52-1.98	3.05	0.28-33.0
Subjects aged 45 yrs or over (129 pairs)						
No formal education	65.9	57.1	1.70	0.98-2.94	3.26*	1.08-9.81
Current smoker	26.4	14.7	2.12†	1.20-3.73	4.27†	1.40-13.0
Sleep disorders (<6 h)	39.5	25.4	2.07†	1.33-3.24	1.31	0.50-3.44
Regular consumption of alcohol	69.0	46.3	2.27†	1.45-3.57	1.86	0.83-4.14
Presence of disease	49.6	29.9	2.48†	1.49-4.12	3.12†	1.32-7.34
Risk-taking behaviour	61.2	11.3	10.04‡	5.23-19.3	7.57‡	2.79-20.5
Large family (≥5 dependants)	54.3	21.5	4.96‡	2.66-9.25	7.08‡	2.42-20.6
Job-related hazards						
Hand tool-related hazards	26.4	13.6	2.62‡	1.38-5.00	1.88	0.57-6.15
Material handling -related hazards	55.0	21.5	4.58‡	2.71-7.73	6.23†	2.12-18.3
Machine-related hazards	48.1	28.8	2.00†	1.28-3.10	0.87	0.33-2.25
Environment/working condition-related hazards	70.5	53.7	1.95*	1.23-3.08	4.01†	1.70-9.50
Geological/strata control-related hazards	65.9	39.0	2.54‡	1.64-3.94	2.37*	1.10-5.12
Electrical equipment-related hazards	29.5	18.6	1.55	0.90-2.66	0.67	0.18-2.41
Haulage-related hazards	25.6	19.2	1.32	0.76-2.29	1.01	0.24-4.20
Blasting-related hazards	25.6	18.6	1.24	0.69-2.23	0.55	0.12-2.50

*$p < 0.05$
†$p < 0.01$
‡$p < 0.001$

ratio of 3.17. This finding could be explained by the fact that older workers tend to be wiser and to know their limits better than their younger colleagues. The role of sleep disorders in injury has been identified by several researchers. Chau *et al.* (2004)[18] found that individuals with sleep disorders reported a twofold higher risk of occupational injury. Akerstedt *et al.* (2002)[23] also observed that difficulties in sleeping strongly predicted fatal accidents. So this study strongly suggests that workers who do not sleep well should be helped to be cautious when they are engaged in dangerous work.

The association between presence of disease and occupational injury is well known.[9,18] This study found that disease was a significant risk factor for subjects aged 45 years or over. The occurrence of injury may be higher among the older group due to a relationship with presence of disease (adjusted OR 3.12). According to Mitchell (2005),[24] an ageing workforce is a challenge to corporate health and the productivity of an employer. In the mining industry, the long-term working experience generates musculoskeletal disorders and cardiovascular diseases. Chau *et al.* (2008)[13] stated that the incidence of injury would increase in coming years due to longer working lives, which would result in more workers with disease and disability. This would be a major occupational health issue for the mining industry. Musculoskeletal disorders are common among miners, and lead to pain affecting the neck, elbows, arm and shoulders, and alter the ability to work. A study by Prabhakar (2006)[25] used the Standard Nordic Questionnaire and the Body Part Discomfort Interview Guide to show that a group of drillers often suffered from musculoskeletal disorders affecting a number of body parts such as the neck, shoulder, knees, back and elbow. In the present study, miners suffered from pneumoconiosis, other respiratory diseases, hypertension, other cardiovascular diseases, and vision disorders. Discussions with the occupational physician suggested that efforts should be made to detect and monitor various diseases. Our results demonstrate that preventive measures that improve working conditions and reduce work-related diseases would strongly decrease the risk of occupational injury. Preventive measures should also include health education programmes at both individual and workplace levels. They should focus on awareness of the risk of injury associated with environmental hazards and working activities, presence of diseases, and unhealthy behaviours such as alcohol consumption and tobacco use.

Smoking was associated with occupational injury for the workers aged 45 years or over. Smoking generates a number of diseases, plays a role in sleep disorders, and affects neuromuscular and physical functions.[26–28] According to Mitchell (2005)[24], the presence of risk factors such as smoking, lack of exercise and obesity could result in higher health care costs for older workers than for their younger counterparts. Regular consumption of alcohol was found to be significant for subjects aged less than 45 years and non-significant for those aged 45 years or over when controlling for all the factors studied. Alcohol use is causally related to a number of diseases, medical conditions, and disabilities.[13,28,29] It can increase the risk of injury by increasing risk-taking behaviour or by reducing perception of, and response to, hazards.[14] Our findings suggest that interventions may help workers, particularly the younger ones, to reduce alcohol intake. For example, an alcoholmeter could be used to assess levels at the beginning of each of the three shifts.

Job-related hazards

Material handling-related hazards were found to be a strong risk factor for injuries compared to other job hazards. This study showed them to be associated with a fivefold higher risk of injury, and the risk levels were close in the two age groups (ORa 6.23 for the subjects aged 45 years or over and 7.32 for those under 45). It was revealed that most injuries occurred when: loading and unloading materials (bolts, resins, plates, mesh, girders, coal, rocks) at the faces, maintaining/repairing machines, and moving power cables and other auxiliary materials. It is suggested that safe lifting procedures should be developed by the mine management to cover the different operations involving materials handling. Moreover, the workers should be helped to change their behaviour and attitudes and to become more aware of the risks involved.

Our study found that the risks of most hazards were similar in the two age groups while the role of machine-related hazards is higher for the workers aged less than 45 years, and that of environment/working condition-related hazards is higher for the subjects aged 45 years or over. The finding for machine-related hazards was supported by a study conducted by Groves *et al.* (2007)[30] in the USA mining industry. They found that young workers had a higher estimated risk index of non-fatal injury and most injuries involved workers with less than 5 years' experience of using the mining equipment concerned. The present study suggests that mine managements should make additional efforts to develop new and creative approaches to training miners, particularly younger ones. Geological and strata control-related hazards were associated with an increased risk of injury and the ORa was significant for workers aged 45 years or more and close to significance for those aged under 45 when adjusting for all factors considered. This was to be expected because geological and strata-control hazards occur in most underground mining operations and are a major problem in underground coalmines. Most of the underground workers in this study were exposed to weak roof strata and unexpected discontinuities in the roof. Geological defects such ase slip planes, faults, clay veins, and joints, may not adequately taken into account when supporting the roof.

Conclusion

The present study sheds light on the risk patterns of injury in a population of underground coal miners including two age groups (under 45 years and over 45 years). Individual factors, namely lack of formal education, sleep disorders, alcohol consumption, disease, having a large family, and risk-taking behaviour were the main risk factors for the total population and their roles were different for the two age groups. Job-related hazards associated with material handling, poor environmental/working conditions, and geological/strata-control-related hazards were the main risk factors ($2.35 \leq ORs \leq 5.15$), and the risks were similar for the two age groups. Machine-related hazards were more important among subjects aged less than 45 years, and environment/working condition-related hazards affected more of the older group. Prevention should aim at reducing job related-hazards. Interventions involving occupational physicians, safety officers, and mine managers to prevent work-related diseases and to improve health status and health-related behaviours (smoking and alcohol) are needed to reduce occupational injuries. It is necessary to promote behavioural approaches to safety management, and particularly to motivate workers to take workplace safety seriously. Mine managers should address the need to reduce environment/working condition-related hazards and geological/strata-control hazards. With regard to materials handling, specific training modules should be developed to improve job knowledge and promote safe lifting techniques.

Acknowledgements

The authors wish to acknowledge the financial support provided by the Ministry of Human Resource Development (MHRD), Government of India for conducting this study. The support from the management, staff and workers of the case study mines is gratefully appreciated.

References

1. NAKATA, A., IKEDA, T., TAKAHASHI, M., HARATANI, T., FUJIOKA, Y., FUKUI, S., SWANSON, N.G., HOJOU, M., AND ARAKI, S. Sleep-related risk of occupational injuries in Japanese small and medium-scale enterprises. *Industrial Health*, vol. 43, 2005, pp. 89–97.

2. TAKALA, J. Introduction to integrated and strategies approach to occupational health. ILO (ed.), *In focus Program on Safety and Health at Work and the Environment*. Presentation on the thirteenth session of the ILO/WHO Joint Committee on Occupational Health, Geneva, 9–12 December, 2003 (www.ilo.org/safework) (accessed 2007-02-10).

3. HERMANUS M.A. Occupational health and safety in mining – Status, new developments, and concerns. *The Journal of the South African Institute of Mining and Metallurgy*, vol. 107, no. 8, 2007, pp. 531–538.

4. KISNER, S.M. Work-related fatalities in the United States: 1980–1995. *Proceedings of the 5th World Conference on Injury Prevention and Control.* New Delhi, March 5–8, 2000, pp. 779.

5. ESTERHUIZEN, G.S. and GURTUNCA, R.G. Coal mine safety achievements in the USA and the contribution of NIOSH research. *The Journal of South African Institute of Mining and Metallurgy*, vol. 106, no. 12, 2006, pp. 813–820.

6. SHARMA, M.M. Mines safety in India-Emerging Issues. Das, S.K. and Bhattacherjee, A. (Course Coordinators) Short-Term Course on Mines Safety and Legislation. March 19-23, 2007, Kharagpur: Indian Institute of Technology, pp. 108–125.

7. KARRA, V.K. Analysis of nonfatal and fatal injury rates for mine operator and contractor employees and the influence of work location. *Journal of Safety Research*, vol. 36, 2005, pp. 413–421.

8. KIZIL, G.V. and JOY, J. The Development and Implementation of a Minerals Industry Risk Management Gateway. *APCOM 2005*. Tucson, Arizona, USA.

9. CHAU, N., MUR, J.M., BENAMGHAR, L., SIEGFRIED, C., DANGELZER, J.L., FRANCAIS, M., JACQUIN, R., and SOURDOT, A. Relationships between some individual characteristics and occupational accidents in the construction industry—A case-control study on 880 victims of accidents occurred during a two-year period. *Journal of Occupational Health*, vol. 44, 2002, pp. 131–139.

10. GHOSH, AK., BHATTACHERJEE, A., and CHAU, N. Relationships of working conditions and individual characteristics to occupational injuries: a case-control study in coal miners. *Journal of Occupational Heath*, vol. 46, 2004, pp. 470–478.

11. GAUCHARD, G.C., MUR, J.M., TOURON, C., BENAMGHAR, L., DEHAENE, D., PERRIN, P., and CHAU, N. Determinants of accident proneness—A case-control study in railway workers. *Occupational Medicine*, vol. 56, 2006. pp. 187–190.

12. IOANNIS, S.B., GEORGE, C.B., ARISTIDES, B.Z., VASSILIKI, B., and PANAYOTIS, N.S. Factors affecting the risk of hip fractures Injury. *International Journal of the Care of the Injured*. vol. 38, 2007, pp. 735–744.

13. CHAU, N., BOURGKARD, E., BHATTACHERJEE, A., RAVAUD, J.F, CHOQUET, M., and MUR, J.M. Group Lohardicap: Associations of job, living conditions and lifestyle with occupational injury in working population: a population-based study, *Int Arch Occup Environ Health*, vol. 81, 2008, pp. 379–389.

14. NORTHEY, G. Alcohol and Injury. A selective annotated bibliography. *Injury Prevention Research Centre Report*. New Zealand: University of Auckland, Series No. 70, 4–5,2003.

15. BHATTACHERJEE, A., KUNAR, B.M., and CHAU N. Contribution of physical hazards and health-related factors in occupational injuries of underground coal miners: A matched case-control study. *Proceedings of the 32nd International Conference of Safety in Mines Research Institutes* (SIMRI). Beijing, China, September 28–29, 2007, SAWS, China, pp. 423–430.

16. GAUCHARD, G., CHAU, N., TOURON, C., BENAMGHAR, L., DEHAENE, D., PERRIN, P., and MUR, J.M. Individual characteristics in occupational accidents due to imbalance—A case control study in the employees of a railway company. *Occupational and Environmental Medicine*, vol. 60, 2003, pp. 330–335.

17. DIRECTORATE GENERAL OF MINES SAFETY. Standard Note, 2007, pp. 1–53.

18. CHAU, N., MUR, JM., BENAMGHAR, L., SIEGFRIED, C., DANGELZER, JL., FRANCAIS, M., JACQUIN, R., and SOURDOT, A. Relationship between certain individual characteristics and occupational for various jobs in the construction industry—A Case-Control Study. *American Journal of Industrial Medicine*. vol. 45, 2004, pp. 84–92.

19. JORGENSEN, K. Concepts of accident analysis. International Labour Office (ILO). (ed.). *Encyclopaedia of Occupational Health and Safety*. Chapter VIII. Accidents and safety management—Accident prevention, 4th ed. Geneva: ILO 1998.

20. CHAU, N., GAUCHARD, G.C., DEHAENE, D., BENAMGHAR, L., TOURON, C., PERRIN, P., and MUR, J.M. Contribution of occupational hazards and human factors in occupational injuries and their association with job, age and type of injuries in railway workers. *International Archives of Occupational and Environmental Health*, vol. 80, no. 6, 2007, pp. 517–525.

21. CHAU, N., RAVAUD, J.F., OTERO, S.C., LEGRAS, B., MACHO, J., GUILLEMIN, F., SANCHEZ, J., and MUR, J.M. Groupe Lorhandicap. Prevalence of impairments and social inequalities: A community-based study in Lorraine. *Rev Epidemiol Sante Publiqu.*, vol. 53, 2005, pp. 614–628.

22. STATA CORPORATION. Stata Statistical Software: release 9.0. College Station, TX, Stata Corporation, 2005.

23. AKERSTEDT, T., KNUTSSON, A., WESTERHOLM, P., THEORELL, T., ALFREDSSON, L., and KECKLUND, G. Work organisation and unintentional sleep-Results from the WOLF study. *Occupational and Environmental Medicine*, vol. 59, 2002, pp. 595–600.

24. MITCHELL, K. Aging workforce challenge to corporate health and productivity. *The Journal for the Financial Services Industry*. 2005, pp. 1–2.

25. PRABHAKAR, D. Human Factors study on drillers. M.Tech Thesis. Dept. of Mining Engineering, IIT Kharagpur, 2006 (Unpublished).

26. HOFFSTEIN, V. Relationship between smoking and sleep apnea in clinic population. *Sleep*, vol. 25, 2002, pp. 519–524.

27. NELSON, H.D., NEVITT, M.C., SCOTT, J.C., STONE, K.L., and CUMMINGS, S.R. Smoking, alcohol, and neuromuscular and physical function of older women. Study of Osteoporotic Fractures Research Group. *JAMA*. vol. 273, 1994, pp. 1825–1831.

28. DAHLGREN, G. and WHITEHEAD, M. Levelling up (Part 2): A discussion paper on European strategies for tackling social inequities in health. Copenhagen: World Health Organization Regional Office for Europe. *Studies on Social and Economic determinants of Population*; no. 3, 2006.

29. ROOM, R., BABOR, T., and REHM, J. Alcohol and public health. *Lancet*, vol. 365, 2005, pp. 519–530.

30. GROVES, W.A., KECOJEVIC, V.J., and KOMLJENOVIC, D. Analysis of fatalities and injuries involving mining equipment. *Journal of safety Research*, vol. 38, 2007, pp. 461–470. ◆