Associations Between Occupational Factors and Occupational Injury and the Interplay of Personal Factors in Indian and French Coal Miners

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ABSTRACT

Research studies during the last decade have shown the roles of occupational and individual factors in occupational injury but a few information is available regarding their interplay. This study aimed at assessing the roles of occupational hazards and exploring their contributions to the occurrences of injuries among the Indian and French coal miners.

In this study two surveys were conducted. The survey in India was a matched case-control study including 245 miners with an occupational injury during the previous two-year period and 245 controls with no injury from two underground coal mines located in the southern part of India. A standardized questionnaire was completed by trained personnel through face-to-face interviews. It included age, experience, sleep disorders, regular alcohol consumption, chronic diseases, smoking habit, number of dependents, occupation, and occupational hazards. The survey in France was a retrospective study on 516 coal miners randomly selected among those aged 32-47 years, from underground mines located in the north-eastern France. The subjects completed a questionnaire including socio-demographic characteristics, health-related behaviours, obesity, chronic diseases, psychotropic drug use, self-reported personality traits, a 14-item biomechanical exposure scale, a 4-item physical exposure scale, and injury during the last two years. The data were analyzed using logistic model for the coal mines in France. The conditional logistic model was used for the matched case–control data from Indian mines.

The annual rate of injuries (with sick leave) was 2.7% for the coal miners in India and 14.9% for the coal miners in France. Logistic model including all occupational factors showed that for the Indian coal miners, material handling had the highest OR (odds ratio) (3.30), followed by machine-related hazards (2.64), hand tool-related hazards (2.21), environment/work conditions (2.10), and geological/strata control (2.01). Further adjustment for personal factors led to a substantial decrease in the OR for hand tool-related hazards (OR 1.24, reduction: 80%) and machine-related hazards (OR 1.19, reduction: 88%) and to a substantial increase in the OR for material handling (OR 5.15, -80%), environment/work conditions (OR 2.63, -48%), and geological/strata control (to 2.35, -34%) for Indian mines. Among the French coal mines, the ORs were 3.01, 3.47, 7.26 for biomechanical *exposure scores 1-4, 5-7, and ≥ 8, respectively (vs. score 0). For French coal miners, personal factors contributed to <6% of the biomechanical exposure-injury association. Among Indian coal miners, hand tool-related and machine-related hazards were significant for the <45 age group only and further adjustment for personal factors led to a decrease in their ORs by 91% and 35%, respectively. The OR for material handling increased by 513% for the <45 years age group and by 77% for the older age group. The OR for environment/work conditions increased by 65% for the <45 years age group and by 204% for the older age group. Among French coal miners further adjustment for personal factors increased the OR by 11% for the <40 years age group and decreased the OR by 26% for the older age group.*

Coal miners from India and France were exposed to numerous occupational hazards which played high roles in occupational injury. Personal factors had a modest confounding role among French coal miners. About the Indian coal miners, it may possibly be inferred that the combined role of personal factors increased the risk of injury for some occupational hazards such as hand tool-related hazards and machine-related hazards This knowledge may be useful when designing prevention for occupational injury.

Keywords: Occupational injury, Occupational exposures, Individual characteristics, Health-related factors, Health-related behaviours, Interplay

INTRODUCTION

Each year approximately 100 millions of occupational injuries occur worldwide (Leigh et al., 1990). Statistical approach based on Poisson and negative binomial distributions has shown that all individuals do not have an equal liability to accidents; that is, accidents are not random events, and that individuals have differential liability to accidents/injuries due to enduring occupational and individual characteristics (Clarke, 2011). Occupational injuries are determined by an imbalance between adverse work conditions and the ability of workers to deal with them. Adverse working conditions include a wide range of biomechanical exposure, physical exposure, psychological demands related to the particular tasks carried out, the workplace environment, issues regarding posture, the materials and tools used, organizational factors, and pressure from management to achieve production targets by working quickly (Leigh et al., 1990; Melamed et al., 1999; Sprince et al., 2002; Ghosh et al., 2004; Chau et al., 2004, 2007, 2011).

Workers' ability to deal with injury risk depends on the extent of adverse work conditions. Employers consider occupational exposures to hazards at a workplace by workforce to be a normal procedure. Year after year and worldwide, this phenomenon is borne by the workers which results in high injury rate for some particular tasks. The injury risk is also assumed as it can occur because of individuals characteristics such as social stratification factors including low education, lower socio-occupational category, younger or older ages, unhealthy behaviours (smoking, alcohol misuse, obesity, lack of leisure physical and sports activity), altered health status, and chronic diseases. Research studies during the last two decades have shown that these factors influence the injury risk through physical/mental capacity, knowledge, experiences, risk perception, and perceived prevention benefits. Both occupational and personal factors are known as strong potential contributors to social inequalities in accidents, health and mortality (Baumann et al., 2007; Khlat et al., 2008; Niedhammer et al., 2011).

Most employers hire workers and cannot offer them safe working environment. As a result, after several years of working, diseases or a premature weakling may lead to workers to be more prone to certain types of occupational injuries (Chau et al., 2010, 2011). Furthermore, many workers consume substances to cope with adverse work conditions, which also contribute to an alteration of health status and working capacities (Chau et al., 2009; Legleye et al., 2011). Those people need to be monitored and are to be given appropriate jobs in order to reduce their injury risk. But, such opportunity is often rare, especially in the current socioeconomic context where available jobs are much less than job aspirants. Many workers return to the same jobs while their health status demands a rest, a recovery period, or an alternate petty job. This practice may lead to injury risk due to occupational factors. In a prevention policy perspective, it is thus important to know the role of occupational factors in occupational injury, and also the confounding roles of personal factors, and their contributions to the associations between occupational factors and occupational injuries. Those issues may differ between mining sites and may vary with workers' age. Exploring these issues in the context of coal miners from India and France may help to understand the injury mechanism in different working conditions.

Old age is associated with better job experience, job knowledge and risk awareness especially in terms of occupational hazards and the capability of the workers to face with them. Old age and some personal factors (such as diseases or personality traits) may thus lead the subjects to be more aware of the injury risk and adopt protective behaviours. However, when occupational hazards are numerous and demanding, their protective behaviours may not be sufficient and their less capacity may lead to a higher risk of injury. Young age is associated with lack of know-how and job knowledge, especially for handling tools (Chau et al., 2007). The coal miners from India and France are of particular interest in this study because their annual rate of occupational injury (with sick leave) is very different (3% and 15%) and their occupational and personal characteristics are also different.

In this paper the following questions are addressed: (1) do injury risks associated with occupational factors differ between coal miners in southern India and those in north-eastern France?; (2) do personal factors play a confounding role and what is their contribution to the explanation of the occupational factor-occupation injury associations and (3) do the role of occupational factors and the confounding role of personal factors vary across age groups?

MATERIALS AND METHODS

Indian Coal Miners

Epidemiological studies are used as a tool for risk analysis and are very much popular in addressing health and safety issues of workers. This survey was a case-control study conducted in 2005 on workers from two underground coal mines located in the southern part of India, which employed 2,376 miners during the period 2003-2004. Both the mines belong to the same coal company. The method of coal extraction was mainly bord and pillar technique. The face mechanization at both the mines is mainly semi-mechanised working which consists of drilling, blasting, load-haul-dumper and side-discharge-dumper loading, and chain conveyor/mine cars transporting. The average total annual production from the mines was 400,000 tons. Only male workers were employed in the mines. Half of the workers were illiterate. The working duration of a worker was eight hours per day and six days per week. Mine 1 experienced maximum number of fatal, serious and reportable injuries compared to Mine 2. Total number of fatal, serious, reportable and minor injuries in the two mines during the 2-year period (2003-2004) was 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) (Directorate General of Mines Safety, 2007). According to the DGMS, fatal injury results in death of one or more persons. Serious injury is defined as an injury which 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 which 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.

The cases were the subjects who faced at least one injury during the two-year period 2003-2004 (annual incidence rate of injury 5.5%). All the injured persons from the mines participated in the study. In total, there were 245 workers with at least one injury who participated in this study and 8 of them had two or more injuries; and there were 9 lost cases (2 fatal injuries and 7 retirements who left the place of the mine premises). The controls were the subjects who did not face any injury during the past five years. For each case, two controls were randomly selected from the non-injured population of the mines based on matching criteria age and job. However, for 85 cases two controls were available. But for the other 160 cases two eligible controls were not available, and consequently only one control was selected for every case. So, in total, 330 controls were included in the study.

The survey was a matched case-control study which was conducted on 245 case-control pairs. The mine management introduced the interview team to the workers. A standardized questionnaire was completed by trained personnel through face-to-face interviews. It included age, experience, sleep disorders, regular consumption of alcohol, smoking habit, number of dependents, occupation, occupational hazards, and occupational injuries during the previous two-year period (2003-2004).

Concerning the job hazards, 8 hazard categories were studied: hand tool, handling material, poor environmental/working conditions, machine related, geological/strata control related, blasting related, electric equipment related and haulage related hazards. Each hazard category was assessed by one or several items. The number of items considered in eight hazard categories was as follows: I. Hand tool hazards with 1 item; II. Handling material hazards with 1 item; III. Environmental hazards with 8 items; IV. Geological and strata control hazards with 5 items; V. Machine related hazards with 5 items. VI. Electric equipment related hazards with 3 items; VII. Blasting related hazards with 2 items; and VIII. Haulage related hazards with 2 items. The interviewed team asked the workers to indicate whether they were exposed to every hazard for the period before and until the occurrence of the last occupational injury. Further details of this study are available in the published research paper by kunar et al.(2010).

French Coal Miners

The sample included 700 male workers randomly selected among all the miners, aged 32-47 years, who worked in underground mines of the Lorraine collieries. The limitation to the age group of 32-47 years was explained by two reasons: to have sufficient exposure duration, and the miners are retired after 48 years. Out of 700 coal miners contacted, 516 subjects participated in the study (74%). The investigation had received a favorable view from the "*Comité Consultatif pour la Protection des Personnes se prêtant à des Recherches Biomédicales*" and the "*Commission Nationale de l'Informatique et des Libertés*", and a written consent was obtained from the participants.

The miners were invited to the occupational medicine center for medical examination. The study protocol included: (1) a letter requesting participation with a standardized auto-questionnaire given by the occupational physician during medical examination; then (2) two solicitations with questionnaires were sent to miners' home addresses through mail at two-month interval. The anonymous standardized self-administered-questionnaires were completed by the subjects themselves and were sent back to the Inserm unit via pre-paid envelops.

The occupational injury was defined as damage to body which resulted from an accident at work with a sick leave of at least one day in addition to the day when the accident occurred and for which the subject got compensation. A two-year period was chosen to have a sufficient number of occupational injuries.

Occupational factors were assessed by a 14-item biomechanical exposure scale (including use of hammer, power hammer, pneumatic tools, other vibrating hand tools, vibrating platform, bent trunk, awkward posture, noise, heat, standing about and walking, restricted space, tasks at height, work in adverse climate, handling objects, overall job tasks for trunk, upper limbs and lower limbs, pain caused by work, and muscular tiredness at the end of a working day) and a 4-item physical exposure scale (exposure to noise, cold or hot temperatures, or outdoor work) (High or very high / absent, low or moderate) (Bhattacherjee et al., 2007; Niedhammer et al., 2011). These biomechanical and physical exposures had scale reliability coefficients of 0.89 and 0.57, respectively. Biomechanical exposure was defined by the number of items (range 0-14), which was then divided up into four categories: 0, 1-4, 5-7, and 8 or over (which corresponded approximately to the quartile values). Physical exposure was defined by the presence of at least one item.

"Personal factors" included body mass index, smoking habit, alcohol misuse, perceived health-status, chronic diseases diagnosed by the physician, frequent "psychotropic" drug use (for headache, tiredness, and nervousness or anxiety, insomnia) (Challier et al., 2000). Alcohol abuse was measured using the French version of the Cut/Annoyed/Guilty/Eye-opener (CAGE) questionnaire (Beresford et al., 1990) and defined by at least two positive responses to four items: consumption considered excessive by the subject, consumption considered excessive by people around the subject, subject wishes to reduce consumption, and consumption on waking. With regard to personality, subjects were asked whether they considered themselves: sociable, organized, aggressive (Yes / No) (Chau et al., 1995; Challier et al., 2000). Further details on the design of the study can be found in the published research paper by Bhattacherjee et al. (2007).

Statistical Analysis

Logistic model (for paired data for Indian case-control study), which yields odds ratios (ORs), was used to examine the associations between occupational and personal factors and occupational injury. First, crude ORs were computed. Then, two-model runs were performed: a basic model including all occupational factors only, which yields adjusted odds ratios (OR1) and a full model including all occupational and personal factors, which yields fully adjusted odds ratios (OR2). The contribution of personal factors to the explanation of the occupational factors-occupation injury associations was estimated by the change in the odds ratios for occupational factors after inclusion of personal factors in the model; that is, explained fraction calculated by the formula: (OR1 – OR2)/(OR1 – 1) (Lynch et al., 1996). Positive % values indicate reductions in ORs, and negative % values increases in ORs. The contribution was calculated only if OR1 was significant. Next, similar analysis was made for different age groups to assess the role of occupational factors and the contribution of personal factors in those age groups. The analyses were performed using the Stata program (Texas: Stata Corporation, 2007).

RESULTS

The annual rate of injury (with sick leave) was much higher among French coal miners (14.9%) than among Indian coal miners (2.7%). The characteristics of the samples are shown in Table 1. We found significant crude ORs for hand tool-related hazards, material handling, machine-related hazards, environment/work conditions, geological/strata control-related hazards among Indian coal miners and a dose-effect relationship for biomechanical exposure among French coal miners. Regarding personal factors, the significant ones were no-formal-education, sleep disorders, regular alcohol use, chronic disease, risk-taking behaviour, and large family (5+ persons) among Indian coal miners. For French coal miners the significant factors were not-good health status, psychotropic drug use, being aggressive, and being sociable or organised (protective factors).

Logistic model including all occupational factors reveals the same occupational factors were significant but with odds ratios (OR1) greatly changed as a result of their roles and interplay in occupational injury (Table 2). Among Indian coal miners material handling had the highest OR1 (3.30), followed by machine-related hazards (2.64), hand tool-related hazards (2.21), environment/work conditions (2.10), and geological/strata control-related hazards (2.01). Among French coal miners, the OR1s were 3.01, 3.47, 7.26 for biomechanical exposure scores 1-4, 5-7, and 8 or over, respectively (vs. score 0).

Table 2 reveals that further adjustment for personal factors led to a substantial decrease in the ORs for hand tool-related hazards (to 1.24, non-significant, 80%) and machine-related hazards (to 1.19, NS, 88%) and to a substantial increase in the ORs for material handling (to 5.15, -80%), environment/work conditions (to 2.63, -48%), and geological/strata control-related hazards (to 2.35, -34%) for Indian miners. For French miners, the personal factors studied contributed to less than 6% of the biomechanical exposure-injury association.

Table 3 reveals that the risk patterns differed significantly across age groups in Indian as well as in French miners. Among Indian miners, hand tool-related and machine-related hazards were significant for the subjects under 45 years only and further adjustment for personal factors led to a decrease in the ORs by 91% and 35%, respectively. The OR for material handling increased by 513% for the subjects under 45 years and by 77% for the subjects aged $\geq$ 45 years. The OR for environment/work conditions increased by 65% for the subjects under 45 years and by 204% for the subjects aged $\geq$ 45 years. Among French miners further adjustment for personal factors increased the OR by 11% for the subjects under 40 years and decreased the OR by 26% for the subjects aged $\geq$ 40 years.

DISCUSSION

The present study sheds light on the roles played by occupational hazards to occupational injury and the confounding role and interplay of personal factors in Indian and French workers from the coal mining industry with different socioeconomic and occupational background. This is of particular interest in the context where young people (especially manual workers) are inducted in workforce with bare minimum training while; in many countries, old workers are to be retained in the workforce to maintain their social status and income. In addition, old workers, especially those around retirement age, are more prone to loss their jobs and become unemployed, because of poor health status or effects of an injury, that may lead to a deteriorated family/social situation and premature mortality (Bartley, 1994; Martikainen et al., 1996; Akinwale et al., 2010; Niedhammer et al., 2011).

The choice of the populations in this study was motivated by the high injury rates of the workers and their longer duration of working in underground mines so that they have a good knowledge on job and

Table 1: Characteristics of the samples: %, crude odds ratio and 95% confidence interval

Indian Coal Miners (N=245 Case-control Pairs)					*French Coal Miners (N=516)*			
	Cases %	*Controls %*	*OR*	*95% CI*		*%*	*OR*	*95% CI*
Occupational factors					**Occupational factors**			
Hand tool-related	30.2	12.4	3.00‡	1.94-4.65	Biomechanical exposure			
Material handling	51.4	19.7	4.12‡	2.83-5.99	Score 0	21.9	1.00	
Machine-related	48.2	24.5	2.50‡	1.79-3.49	1-4	29.1	2.54†	1.33-4.87
Environment/work conditions	70.6	57.0	1.67†	1.19-2.34	5-7	21.5	2.76†	1.40-5.45
Geological/strata control	62.4	41.8	2.21‡	1.60-3.06	• 8	27.5	5.36‡	2.84-10.1
Electrical equipment	24.5	19.1	1.25	0.82-1.90	Physical exposure	69.2	1.22	0.80-1.84
Haulage	20.8	18.2	1.10	0.72-1.68	**Personal factors**			
Blasting	22.9	18.8	1.14	0.73-1.76	Age: mean (SD) (yr)	39 (3.5)	0.98	0.92-1.03
Personal factors					Current smoker	40.7	0.97	0.66-1.43
No formal education	62.9	50.9	1.95‡	1.31-2.91	Alcohol misuse	11.4	1.13	0.63-2.03
Current smoker	21.2	16.1	1.47	0.95-2.25	Obese	12.3	1.51	0.88-2.62
Sleep disorders (<6 h)	50.2	28.5	2.30‡	1.69-3.14	Not-good health status	52.5	1.99‡	1.35-2.93
Regular alcohol use	67.8	41.5	2.52‡	1.82-3.50	Chronic disease			
Chronic disease	53.1	29.4	2.94‡	2.01-4.29	Musculoskeletal	54.3	1.60*	1.09-2.35
Risk taking behaviour	59.6	11.2	8.66‡	5.54-13.5	Others	30.6	1.04	0.69-1.56
Large family (5+ persons)	53.9	22.1	4.44‡	2.88-6.83	Psychotropic drug use	29.3	1.98‡	1.33-2.96
					Self-reported personality traits			
					Sociable	45.7	0.67*	0.46-0.99
					Aggressive	5.4	2.13*	1.00-4.59
					Organized	36.6	0.65*	0.44-0.98

*p<0.05, †p<0.01, ‡p<0.001.

Table 2: Associations of occupational injury with occupational and personal factors: adjusted OR and 95% confidence interval

Indian Coal Miners (N=245 Case-control Pairs)						*French Coal Miners (N=516)*					
	OR1	*95% CI*	*OR2*	*95% CI*	%		*OR1*	*95% CI*	*OR2*	*95% CI*	%
Occupational factors						**Occupational factors**					
Hand tool-related	2.21†	1.26-3.87	1.24	0.52-2.96	80	Biomechanical exposure					
Material handling	3.30‡	2.08-5.24	5.15‡	2.36-11.2	-80	Score 0	1.00		1.00		
Machine-related	2.64‡	1.72- 4.05	1.19	0.90-3.12	88	1-4	3.01‡	1.53-5.94	2.98†	1.48-5.99	3
Environment/work conditions	2.10†	1.37- 3.24	2.63†	1.53-4.69	-48	5-7	3.47‡	1.68-7.15	3.28†	1.55-6.95	5
Geological/strata control	2.01†	1.33- 3.02	2.35‡	1.53-4.69	-34	• 8	7.26‡	3.54-14.9	6.81‡	3.18-14.5	6
Electrical equipment	0.90	0.44-1.83	0.64	0.23-1.79	•	Physical exposure	0.62	0.38-1.02	0.62	0.37-1.03	•
Haulage	0.77	0.40-1.62	0.78	0.23-2.67	•	**Personal factors**					
Blasting	0.89	0.39-2.04	1.13	0.33-3.90	•	Age (yr)			0.96	0.91-1.02	
Personal factors						Current smoker			1.01	0.66-1.54	
No formal education			3.00†	1.38-6.84		Alcohol misuse			0.79	0.42-1.51	
Current smoker			1.79	0.79-4.05		Obese			1.48	0.82-2.70	
Sleep disorders (<6 h)			1.86*	1.01-3.45		Not-good health status			1.67*	1.07-2.59	
Regular alcohol use			2.32†	1.24-4.36		Chronic disease					
Chronic disease			2.23†	1.16-4.26		Musculoskeletal			1.09	0.69-1.71	
Risk taking behaviour			9.40‡	2.63-9.07		Others			0.79	0.50-1.25	
Large family (5+ persons)			5.40‡	2.39-9.27		Psychotropic drug use			1.74*	1.12-2.69	
						Self-reported personality traits					
						Sociable			0.74	0.48-1.13	
						Aggressive			1.44	0.62-3.36	
						Organized			0.74	0.47-1.16	

*p<0.05, †p<0.01, ‡p<0.001.
OR1: odds ratio adjusted for all occupational factors only.
OR2: odds ratio adjusted for all occupational and personal factors.
%= Reduction (positive %) or increase (negative %) in OR computed with the following formula: (OR1 – OR2)/(OR1 – 1) where OR1 are OR in Table 1 and OR2 are those in this Table; calculated for significant OR1 only.

Table 3: Associations of injury with occupational factors: OR and 95% confidence interval

Indian Coal Miners	*OR1*	*OR2*	*%*	*French Coal Miners*	*OR1*	*OR2*	*%*
Age < **45** (N=116)				**Age** < **40** (N=293)			
Hand tool-related	4.18†	1.30	91	Biomechanical exposure			
Material handling	2.03*	7.32†	-513	Score 0	1.00	1.00	
Machine-related	4.62‡	3.34†	35	1-4	2.21	2.17	—
Environment/work conditions	2.26*	3.08*	-65	5-7	3.21*	3.11*	5
Geological/strata control	1.78	2.80	—	≥ 8	7.19‡	7.90‡	-11
Electrical equipment	0.54	0.74	—	Physical exposure	0.77	0.75	—
Haulage	0.73	0.79	—				
Blasting	2.17	3.05	—				
Age ≥ **45** (N=129)				**Age** ≥ **40** (N=223)			
Hand tool-related	1.41	1.88	—	Biomechanical exposure			
Material handling	3.96‡	6.23†	-77	Score 0	1.00	1.00	
Machine-related	1.78	0.87	—	1-4	4.28†	3.91†	11
Environment/work conditions	1.99*	4.01†	-204	5-7	3.51*	3.38*	5
Geological/strata control	2.26†	2.37*	-9	≥ 8	6.73‡	4.96†	26
Electrical equipment	1.60	0.67	—	Physical exposure	0.48*	0.53	10
Haulage	0.67	1.01	—				
Blasting	0.91	0.55	—				

*p<0.05, †p<0.01, ‡p<0.001.
OR1: odds ratio adjusted for all occupational factors only.
OR2: odds ratio adjusted for all occupational and personal factors.
%= Reduction (positive %) or increase (negative %) in OR computed with the following formula: (OR1 – OR2)/(OR1 – 1); calculated for significant OR1 only.

working conditions in order to properly capture their occupational exposures. The annual rate of injury of 14.9% for French miners was very high compared with that for French construction workers (10%) and that for the French working population from the general compensation system (17.2 million workers, 4.3%) (Caisse nationale de l'assurance maladie des travailleurs salariés, 2003). The participation rate was high for Indian miners (100%) as well as for French miners (74%). The narrow age range for French miners resulted from retirement of workers at an early age (48 years).

Although the working conditions differed between Indian and French miners, this study revealed that biomechanical exposure played the main role in occupational injury. Indeed, among Indian miners who had an annual rate of injury of 2.7%, material handling, machine-related hazards, hand tool-related hazards and environment/work conditions were associated with a 2-3 fold higher risk of injury while geological/strata control-related hazards was associated with a 2-fold higher risk of injury. The higher risk for machine-related hazards was consistent with a study in the USA mining industry (Groves et al., 2007). Among French miners who had an annual rate of injury of 14.9%, a dose-effect relationship was found for biomechanical exposure score (measured as the number of perceived high occupational hazards) with a risk reaching 7-fold higher for a score $\geq$ 8, which pointed out the role of cumulative effect of a number of hazards that concerned most miners. Among French miners, the injuries were generally directly related to the tasks and those hazards with increasing tiredness or improper posture had higher risk of injury (data not shown) (Bhattacherjee et al., 2007; Legleye et al., 2011). These findings were expected as most miners were exposed to demanding tasks and they always work in changing hazardous work environment, under freshly exposed roof and on slippery floor condition. In this context, the experience and job knowledge cannot eliminate the injuries when the number of demanding hazards is continuously high. Thus prevention should especially focus on those hazards that affect the working capacity of the workers, and consequently the quality of task performed, alertness, vigilance, and observing the numerous hazards (Härma et al., 1998; Chau et al., 2011).

Our studies found that, like occupational factors, the personal ones, which may affect the working capacity of the workers such as regular alcohol use, sleep disorders, altered health status, frequent psychotropic drug use, and chronic diseases (especially musculoskeletal disorders) also played a role in injury. Lack of education, self-reported personality traits, risk-taking behaviour, and large family were the other known risk factors (Ghosh et al., 2004; Khlat et al., 2008; Chau et al., 1995, 2007, 2011) which were identified in our studies. Strong disparities were observed between Indian and French coal miners in the contribution of the study personal factors to the explanation of the occupational factors and occupational injury. The effect of personal factors was negligible (<6%) among French miners, and this finding suggests that when the injury risk associated with occupational hazards is high, personal characteristics have small confounding influence on it. It should be noted that, among French miners, the recruitment process of workers is selective and the workers take retirement at a young age (48 years). Moreover, the miners had to work in groups/teams so that most demanding and challenging tasks were performed by the workers with better abilities due to their solidarity and the recommendations of the occupational physicians. The workers are not allowed to consume tobacco and alcohol at work, which may have immediate effect on working capabilities (Chau, 2011). Among Indian miners with much lower injury risk, it was observed that the personal factors displayed, on the contrary, marked contributions, which varied a lot across the types of occupational hazards. They explained about 80% of the associations between hand tool-related and machine-related hazards and injury, and this finding highlighted the role of lack of education and other factors related to worker's ability and risk-taking behaviour. Inversely, it may be noted that those personal factors reduced the risk associated with material handling, environment/work conditions and geological/strata control by 34% to 80%. These results may be useful for prevention as they may highlight the risk patterns for various occupational hazards.

An important finding in this study was that the role of occupational hazards in injury and the interplay of personal factors varied across age groups for the two study populations. We found that among Indian miners hand tool-related and machine-related hazards affected the workers aged less than 45 years while materiel handling and geological/strata control-related hazards affected more the older miners. This may point out a lack of knowledge, inexperience or risk averseness among the younger and a lower physical capacity among the older. Experience and job knowledge are acquired through a long period of work (often more than 10 years, Chau et al., 2010; Chau, 2011). It would be of interest to observe that the contributions of personal factors to the explanation of the risks associated with various occupational hazards were as a whole exacerbated among the miners aged less than 45 years while among the older miners by taking into account personal factors we found higher role for environment/work conditions, materiel handling and geological/strata control related hazards. This may suggest that old age group was associated with a better experience, job knowledge and risk awareness. Among French miners the result was different in that, irrespective of personal factors, biomechanical exposure was associated with a similar risk for the scores 5-7 and $\geq$ 8, but the risk was high for a score 1-4 for the miners aged $\geq$ 40 years only. The personal factors explained 26% of the risk associated with a score $\geq$ 8 for the miners aged $\geq$ 40 years, and contributed less for lower scores (between -11% and 11%). Unlike Indian miners, personal factors had positive contributions to the occupational hazards-injury associations among older ages.

This study has some limitations. Firstly, the type of survey was different between the Indian and French miners: a case-control study among Indian miners and a retrospective study among French miners. The Indian survey used face-to-face interview by trained personal while the French survey conducted through a self-administered questionnaire. However, these procedures are common in epidemiological studies. The occupational and personal factors were different between the two surveys. This may correspond to the study populations. Occupational exposures were reported by the subjects. They concerned the period of time before and around the injury occurring. Smoking and alcohol misuse are generally persistent and started from adolescence or young adulthood (Chau, 2011). Chronic diseases were limited to those that had been diagnosed by a physician. The Indian and French miners were not of similar ages because of the young age of retirement for the French miners. The age groups considered were a bit different for the two studies, however, these age groups were chosen to reach a maximum power for statistical tests for each age group. The age thresholds 40-45 years approximately correspond to approximately to the beginning of physical and mental disabilities in the general population (Chau et al., 2005; Loos-Ayav et al., 2007).

CONCLUSION

In conclusion, this study demonstrates that Indian and French coal miners were exposed to a number of occupational hazards, which played high roles in occupational injury. Personal factors had a modest confounding role in French miners. Among Indian coal miners a higher role was found for material handling, environment/work conditions, and geological/strata control when controlling for personal factors in those aged 45 years or over; in the younger miners the interplay of occupation and personal factors depended on the hazards. This knowledge may be useful when designing prevention programs aiming at reducing occupational injury across age groups. Further studies are needed to confirm these findings in other populations.

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