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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

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Abstract
Objective: The role of occupational hazards in occupational injury may be mediated by individual factors across various age groups. This study assessed the role of occupational hazards as well as contribution of individual factors to injuries among Indian and French coalminers. **Material and Methods:** We conducted a case-control study on 245 injured workers and on 330 controls without any injuries from Indian coal mines using face-to-face interviews, and a retrospective study on 516 French coalminers using a self-administered questionnaire including potential occupational and personal factors. Data were analyzed using logistic models. **Results:** The annual rate of injuries was 5.5% for Indian coalminers and 14.9% for the French ones. Logistic model including all occupational factors showed that major injury causes were: hand-tools, material handling, machines, and environment/work-geological/strata conditions among Indian miners (adjusted odds-ratios 2.01 to 3.30) and biomechanical exposure score among French miners (adjusted odds-ratio 3.01 for score the 1–4, 3.47 for the score 5–7, and 7.26 for score ≥ 8, vs. score 0). Personal factors among Indian and French coalminers reduced/exacerbated the roles of various occupational hazards to a different extent depending on workers' age. **Conclusion:** We conclude that injury roles of occupational hazards were reduced or exacerbated by personal factors depending on workers' age in both populations. This knowledge is useful when designing prevention which should definitely consider workers' age.

Key words:
Health-related behaviors, Health-related factors, Individual characteristics, Interplay, Occupational exposures, Occupational injury

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INTRODUCTION

Around 268 million work-related accidents causing at least 3 days of absence from work and 353 204 fatal accidents occurred in 2001 around the whole world [1]. Statistical approach, based on Poisson and negative binomial distributions, has shown that all individuals do not have an equal liability to accidents; i.e., accidents are not random events, and individuals have differential liability to accidents/injuries due to enduring occupational and individual characteristics [2]. Occupational injuries are determined by the imbalance between adverse work conditions and the ability of a worker to deal with them. Adverse working conditions include a wide range of biomechanical exposure, physical exposure, psychological demands related to the particular tasks, workplace environment, issues regarding posture, the used materials and tools, organizational factors, as well as pressure from management to achieve production targets by working quickly [3–10].

Workers' ability to deal with the risk of an injury depends on the extent of adverse work conditions. Employers consider occupational exposure of workforce to hazards in the workplace as a normal procedure. Year after year, worldwide, this phenomenon is a commonplace for workers, which results in high injury rates for demanding tasks. The injury risk can also be influenced by individuals' characteristics such as social stratification factors including low education, lower socio-occupational category, younger or older age, unhealthy behaviors (smoking, alcohol misuse, obesity, lack of leisure physical and sports activity), altered health status, sleep disorders, mental disorders, and chronic diseases [2–5,9–15]. During the last 2 decades research studies have shown that these factors influence the injury risk through physical/mental capacity, knowledge, experience, risk perception, and perceived prevention benefits. Physical, seeing and hearing as well as cognitive disabilities have been reported as strong risk factors because they alter working capacity and reduce perception of occupational hazards and warning sounds [3,11,16]. Both occupational and personal factors may play different roles in various age groups [3,12]. They are known as strong potential contributors to social inequalities in accidents, health and mortality [3,11,17,18].

Most employers hire workers and cannot provide them with a safe working environment. As a result, after several years of working, diseases or a premature weakening may lead to workers being more prone to certain types of occupational injuries [3,12]. Furthermore, many workers consume some substances in order to cope with adverse work conditions, which also contributes to an alteration of health status and working capacities [13,19]. Those people need to be monitored and should be given appropriate job in order to reduce their injury risk. However, such opportunity is often rare, especially in the current socio-economic context where available jobs are much fewer than job aspirants. Many workers return to the same jobs in spite of the fact that their health status demands a rest, a recovery period or an alternate petty job and such a practice may lead to injury risk due to occupational factors. In a perspective of prevention policy, it is thus important to know the role of occupational factors in occupational injury and also the confounding roles of personal factors, as well as their contributions to the associations between occupational factors and occupational injuries. Those issues may differ between mining sites and may vary depending on workers' age. Exploring these issues in the context of coalminers 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 them. Old age and some personal factors (such as diseases or personality traits) may thus lead the subjects to being more aware of the injury risk and adopting protective behaviors. However, when occupational hazards are numerous and demanding, protective behaviors may not be sufficient and smaller capacity may lead to a higher risk of injury [3–4,12,16]. Young age is associated with the lack of know-how and job knowledge, especially for handling tools [4]. The coalminers from India and France are of particular interest in this study, because their annual rate of occupational injuries (with sick leave) is very different (3% and 15%) and their occupational and personal characteristics also vary.

In this paper the following questions are addressed:

1. Do injury risks associated with occupational factors differ between coalminers 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?
3. Does the role of occupational factors and the confounding role of personal factors vary across age groups?

We also explored associations between occupational and personal factors, especially personal health-related factors, which may reveal possible indirect roles of occupational factors in injuries via these health-related factors. It may be noted that coal mining is an industrial sector and because of its hazardous nature most of the workers, both in France as well as in India, are at risk of occupational injuries [20–22]. Furthermore, the annual rate of injuries did not vary over time in France as well as in India even though it has been greatly different (about 14% and 5.5%, respectively) in the 2 countries. Our findings may reveal the injury mechanisms involving potential occupational hazards and the interplay of personal factors and may show their functioning in 2 different populations with different occupational activities and work environment, injury risk level, workers' age, and workers' socio-economic and cultural contexts. Our results can make prevention policy makers realize that injury mechanisms should be evaluated prior to their prevention by considering various occupational hazards and the workers' features in various age groups.

MATERIAL AND METHODS

Indian coalminers

Epidemiological studies are used as a tool for risk analysis and are very popular in addressing health and safety issues concerning workers. This survey was a case-control study conducted on the workers from 2 underground coal mines located in the southern part of India, which employed 2376 miners during the previous 2-year period. Both mines belonged to the same coal company. Only male workers were employed in the mines. Half of the workers were illiterate. On average, working time of a worker was 8 h per day and 6 days per week. During the previous 2 years there were 262 occupational injuries in the 2 mines which resulted in sick leaves for a period exceeding 24 h (annual incidence injury rate of 5.5%) [23]. The cases were the subjects who experienced at least one injury during the previous 2-year period. All the injured persons from the mines participated in the study. In total, there were 245 workers with at least one injury, 8 of them had 2 or more injuries and 9 were lost cases (2 fatal injuries and 7 retired miners who left mine premises). The controls were the subjects who did not experience any injury during the past 5 years. For each case, 2 controls were randomly selected from the non-injured population of miners based on matching criteria i.e., age and job. However, only for 85 cases 2 controls were available. For the other 160 cases, 2 eligible controls were not available so, consequently only one control was selected for every case. Therefore, in total, there were 330 controls included in the study.

The survey was a matched case-control study which was conducted on 245 case-control pairs. The mines' management introduced the interview team to the workers. A standardized questionnaire was completed by trained personnel through face-to-face interviews. It included questions concerning age, experience, sleep disorders, regular consumption of alcohol, smoking habit, number of dependents, occupation as well as occupational hazards and occupational injuries during the previous 2-year period.

With respect to the job hazards, 8 hazard categories were studied (Table 1):
– hand tool hazards with 1 item;
– handling material hazards with 1 item;
– environmental hazards with 10 items;
– geological and strata control hazards with 5 items;
– machine related hazards with 5 items;
– electric equipment related hazards with 1 items;
– blasting related hazards with 1 items;
– haulage related hazards with 1 items.

The interviewed team asked the workers to indicate whether they were exposed to any of the hazards for the period before and until the occurrence of the last occupational injury.

French coalminers

The Lorraine collieries, in the north-eastern France, at the time of the study employed 10 046 underground workers and 5371 surface workers. The study sample included 700 male workers randomly selected of all the miners, aged 32–47 years, who worked in underground mines. Limitation of the age group to 32–47 years was explained by 2 reasons: sufficient exposure duration and retirement after 48 years of age among miners. Out of 700 coalminers 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"

Table 1. Occupational hazards among Indian and French coalminers

Indian coalminers	French coalminers
Hand tool hazards (1 item):	Biomechanical exposures (high or very high vs. absent, low or moderate)
working with a hammer or a power hammer or a crow bar	use of a hammer, a power hammer, pneumatic tools, other vibrating hand tools
Handling material hazards (1 item):	vibrating platform
handling of a heavy object or material or shoveling	bent trunk
Environmental hazards (10 items, presence of at least one item):	awkward posture
heat, noise, dust, improper ventilation, insufficient light, water at workplaces, steep gradient, slippery floor, not taking proper shelter at the time of blasting, and possibility of blown out shots	standing about and walking
Geological and strata control hazards (5 items, presence of at least one item):	restricted space
fault and slip planes	tasks at height
fractured roof	work in adverse climate
failure to identify bad roof	handling objects
improper dressing	overall job tasks for trunk
un-supported roof	overall job tasks for upper limbs
Machine related hazards (5 items, presence of at least one item):	overall job tasks for lower limbs
moving parts of the machine	pain caused by work
unskilled operators	muscular tiredness at the end of a working day
working in close proximity with a conveyor	Physical exposures (high or very high vs. absent, low or moderate)
not adequate safety devices	noise
maintenance schedule of the machines not followed properly	cold temperatures
Electric equipment related hazards (1 item):	hot temperatures
electricity including shock and burns	outdoor work
Blasting related hazards (1 item):	
possibility of blown out shots	
Haulage related hazards (1 item):	
poor quality of existing ropes and rollers	

(national review boards), and a written consent was obtained from all the participants before commencement of the study.

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

Occupational injury was defined as a 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 2-year period was chosen to have a sufficient number of occupational injuries.

Occupational factors were assessed by the use of a 14-item biomechanical exposure scale and a 4-item physical exposure scale (Table 1) [18]. These biomechanical and physical exposures had scale reliability coefficients (Cronbach's α coefficients) of 0.89 and 0.57, respectively. Biomechanical exposure was defined by the number of items (range: 0–14), which was then divided into 4 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 and a frequent "psychotropic" drug use (for headaches, tiredness, nervousness or anxiety and insomnia) [3,11,24]. Alcohol abuse was measured using the French version of the Cut/Annoyed/Guilty/Eye-opener (CAGE) questionnaire and defined by at least 2 positive responses to 4 items: consumption considered excessive by the subject, consumption considered excessive by people around the subject, subject wishes to reduce consumption, and consumption on waking [25].

In the case of disabilities, the following ones were considered: physical, seeing, hearing and cognitive disabilities [3,8,11]. Physical disability was measured with a 5-item scale including: sitting down and getting up (from one's chair, …), walking outside on a flat ground, taking up 5 steps, taking an object weighing 2.5 kg located above one's head, and lowering down to take an object. Seeing and hearing disabilities were measured with a one-item each. Cognitive disability was measured by a 4-item scale including thinking/concentration/attention, orientation, problem-solving and memory. For each item the subjects were asked to "Indicate the response which corresponds to their ability to undertake the following activities". Response options were: with some difficulty, a lot of difficulty or unable to undertake vs. without difficulty. Physical disability and cognitive disability scores had scale reliability coefficients of 0.67 and 0.74, respectively.

With regard to personality, the subjects were asked whether they considered themselves: sociable, organized, aggressive (Yes / No) [24,26].

Statistical analysis

Logistic model (for paired data in the case of the Indian case-control study), which yields odds ratios (ORs), was used to examine associations between occupational and personal factors and occupational injury. First, crude ORs were computed. Then, 2-model runs were performed: a basic model including 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). 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) [27]. Positive % values indicated 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 in order to assess the role of occupational factors and the contribution of personal factors in those age groups. Association between each occupational factor and each personal factor was measured with crude odds ratios. 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 miners (14.9%) than among Indian miners (2.7%). The characteristics of the samples are shown in Tables 2 and 3. For Indian miners, significant crude ORs were found for the hand tool-related hazards, material handling, machine-related hazards, environment/work conditions and geological/strata control-related hazards (ORs reaching: 4.12). The significant personal factors included: no formal education, sleep disorders, regular alcohol use, chronic disease, risk-taking behavior and a large family (ORs reaching: 8.66).
For French miners a dose-effect relationship was found for biomechanical exposure (ORs reaching: 5.36) while the significant personal factors were: not-good health status, psychotropic drug use, musculoskeletal disease, physical, seeing, hearing and cognitive disabilities and being aggressive (ORs reaching: 6.04). Being sociable or organized acted as protective factors.

Table 2. Characteristics of the samples – Indian coalminers

Factors	Cases (N = 245) (%)	Controls (N = 330) (%)	OR (95% CI)
Occupational factors			
hand tool-related	30.2	12.4	3.00*** (1.94–4.65)
material handling	51.4	19.7	4.12*** (2.83–5.99)
machine-related	48.2	24.5	2.50*** (1.79–3.49)
environment/work conditions	70.6	57.0	1.67** (1.19–2.34)
geological/strata control	62.4	41.8	2.21*** (1.60–3.06)
electrical equipment	24.5	19.1	1.25 (0.82–1.90)
haulage	20.8	18.2	1.10 (0.72–1.68)
blasting	22.9	18.8	1.14 (0.73–1.76)
Personal factors			
no formal education	62.9	50.9	1.95*** (1.31–2.91)
current smoking	21.2	16.1	1.47 (0.95–2.25)
sleep disorders (< 6 h)	50.2	28.5	2.30*** (1.69–3.14)
regular alcohol use	67.8	41.5	2.52*** (1.82–3.50)
chronic disease[a]	53.1	29.4	2.94*** (2.01–4.29)
risk taking behavior	59.6	11.2	8.66*** (5.54–13.5)
large family (≥ 5 persons)	53.9	22.1	4.44*** (2.88–6.83)

OR – crude odds ratio; CI – confidence interval.
[a] They were cardiovascular diseases (16.7% in cases and 8.6% in controls), vision disorders (13.5% and 6.6%), musculoskeletal disorders (9% and 3.7%), respiratory diseases (7.5% and 4.5%), and other diseases (6.4% and 5.8%).
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3. Characteristics of the samples – French coalminers

Factors	Sample (N = 516) (%)	OR (95% CI)
Occupational factors		
biomechanical exposure (score)		
0	21.9	1.00
1–4	29.1	2.54** (1.33–4.87)
5–7	21.5	2.76** (1.40–5.45)
≥ 8	27.5	5.36*** (2.84–10.1)
physical exposure	69.2	1.22 (0.80–1.84)
Personal factors		
age: mean (SD) (years)	39 (3.5)	0.98 (0.92–1.03)
current smoking	40.7	0.97 (0.66–1.43)
alcohol misuse	11.4	1.13 (0.63–2.03)
obese	12.3	1.51 (0.88–2.62)
not-good health status	52.5	1.99*** (1.35–2.93)
chronic disease		
musculoskeletal	54.3	1.60* (1.09–2.35)
others	30.6	1.04 (0.69–1.56
psychotropic drug use	29.3	1.98*** (1.33–2.96)
physical disability (score)		
0	80.2	1.00
1–2	15.1	2.46*** (1.49–4.05)
≥ 3	4.7	6.04*** (2.51–14.5)
seeing disability	14.7	1.90* (1.15–3.13)
hearing disability	20.5	1.75* (1.12–2.73)
cognitive disability (score)		
0	66.1	1.00
1–2	23.8	1.26 (0.80–1.97)
≥ 3	10.1	2.15* (1.18–3.90)
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)

Abbreviations as in Table 2.

Logistic model including all occupational factors revealed that the same occupational factors were significant but adjusted odds ratios (OR1) greatly changed as a result of their roles and interplays in occupational injury (Tables 4 and 5). Among Indian miners, material handling had the highest OR1, followed by the machine-related hazards, hand tool-related hazards, environment/work conditions and geological/strata control-related hazards. Among French miners, the dose-effect relationship for biomechanical exposure remained significant (OR1s reaching: 7.26).

Tables 4 and 5 also reveal that further adjustment for personal factors led to a substantial decrease in the ORs for the hand tool-related hazards and machine-related hazards (about 80%), and to a substantial increase in the ORs for material handling, environment/work conditions, and geological/strata control-related hazards (between –80% and –34%) for Indian miners. For French miners, a substantial decrease in the ORs was found for biomechanical exposure: score 1–4 (5%), score 5–7 (18%), and for score ≥ 8 (24%). The OR for physical exposure changed little but became significant (0.59).

Table 6 shows that, among Indian coalminers, no link was found between occupational and personal health-related factors for the control group except for the link between the machine-related hazard and sleep disorders (OR: 2.94). On the contrary, among the cases aged ≥ 45, some associations were observed (ORs reaching: 5.00): smoking with the hand

Table 4. Associations between occupational injury and occupational and personal factors – Indian coalminers (N = 245)

Factors	OR1 (95% CI)	OR2 (95% CI)	Reduction/Increase (%)[a]
Occupational factors			
hand tool-related	2.21** (1.26–3.87)	1.24 (0.52–2.96)	80
material handling	3.30*** (2.08–5.24)	5.15*** (2.36–11.2)	–80
machine-related	2.64*** (1.72–4.05)	1.19 (0.90–3.12)	88
environment/work conditions	2.10** (1.37–3.24)	2.63** (1.53–4.69)	–48
geological/strata control	2.01** (1.33–3.02)	2.35*** (1.53–4.69)	–34
electrical equipment	0.90 (0.44–1.83)	0.64 (0.23–1.79)	–
haulage	0.77 (0.40–1.62)	0.78 (0.23–2.67)	–
blasting	0.89 (0.39–2.04)	1.13 (0.33–3.90)	–
Personal factors			
no formal education		3.00** (1.38–6.84)	
current smoking		1.79 (0.79–4.05)	
sleep disorders (< 6 h)		1.86* (1.01–3.45)	
regular alcohol use		2.32** (1.24–4.36)	
chronic disease		2.23** (1.16–4.26)	
risk-taking behavior		9.40*** (2.63–9.07)	
large family (≥ 5 persons)		5.40*** (2.39–9.27)	

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

Table 5. Associations between occupational injury and occupational and personal factors – French coalminers (N = 516)

Factors	OR1 (95% CI)	OR2 (95% CI)	Reduction/Increase (%)[a]
Occupational factors			
biomechanical exposure (score)			
0	1.00	1.00	
1–4	3.01*** (1.53–5.94)	2.90** (1.43–5.88)	5
5–7	3.47*** (1.68–7.15)	3.02** (1.41–6.48)	18
≥ 8	7.26*** (3.54–14.9)	5.77*** (2.66–12.5)	24
physical exposure	0.62 (0.38–1.02)	0.59* (0.35–0.99)	–
Personal factors			
age (years)		0.94 (0.88–1.00)	
current smoking		1.04 (0.67–1.59)	
alcohol misuse		0.73 (0.37–1.41)	
obese		1.54 (0.84–2.81)	
not-good health status		1.39 (0.87–2.21)	
chronic disease			
musculoskeletal		1.03 (0.65–1.63)	
others		0.78 (0.48–1.24)	
psychotropic drug use		1.62* (1.03–2.55)	
physical disability (score)			
0		1.00	
1–2		1.64 (0.92–2.92)	
≥ 3		3.09* (1.17–8.18)	
seeing disability		1.40 (0.77–2.55)	
hearing disability		1.23 (0.71–2.14)	
cognitive disability (score)			
0		1.00	
1–2		0.98 (0.60–1.63)	
≥ 3		1.04 (0.51–2.14)	
self-reported personality traits			
sociable		0.76 (0.49–1.18)	
aggressive		1.34 (0.56–3.21)	
organized		0.73 (0.46–1.17)	

Abbreviations as in Table 4.

tool-related and electrical equipment hazards; sleep disorders with the material handling and machine-related hazard; and chronic disease with environment/work conditions and geological/strata control. Some associations were even observed among the cases aged < 45 (ORs reaching: 4.23): sleep disorders with the hand tool-related hazard; regular alcohol use with environment/work conditions, electrical equipment, haulage and blasting; and chronic disease with the hand tool-related hazard, environment/work conditions, and the blasting related hazards.

Table 7 shows that, among French coalminers aged < 40, biomechanical exposure was associated with alcohol misuse, musculoskeletal disorders, psychotropic drug use, physical disability and with being sociable, while physical exposure was associated with physical disability. Among the miners aged ≥ 40, biomechanical exposure was associated with alcohol misuse, not-good health status, musculoskeletal disorders, physical, seeing, hearing, and cognitive disabilities, as well as with being aggressive, while physical exposure was associated with hearing disability.

Tables 8 and 9 reveal that the risk patterns differed significantly across various age groups, both in Indian as well as in French miners. Among Indian miners, the hand tool-related and machine-related hazards were significant only for the subjects < 45 years and further adjustment for personal factors led to a decrease in the ORs by 54% and 30%, respectively. The OR for material handling increased by 41% for the subjects aged < 45 and by 77% for those aged ≥ 45. The OR for environment/work conditions increased by 44% for the subjects aged < 45 and by 204% for those aged ≥ 45. Among French miners, biomechanical exposure played similar role for the 2 age groups < 40 and ≥ 40 years, but the score 1–4 was significant for the older group only (OR: 4.28). Further adjustment for personal factors increased the ORs for biomechanical exposure by 25–42% for the subjects aged <40 years and decreased the ORs by 25–43% for the subjects aged ≥ 40. Physical exposure played a protective role among the subjects aged ≥ 40 (OR: 0.48) which increased by 13% along with further adjustment for personal factors.

DISCUSSION

The present study sheds light on the roles played by occupational hazards in occupational injury and the confounding role and interplay of personal factors in Indian and French workers from the coal mining industry with different socio-economic and occupational background. This is of particular interest in the context where young people (especially manual workers) are inducted in workforce with minimum training while, in many countries, older workers are retained in the workforce in order to maintain their social status and income. In addition, older workers, especially those around retirement age, are more prone to lose their jobs and become unemployed because of poor health status or effects of an injury, which may lead to a deteriorated family/social situation and premature mortality [18,28–30].

The choice of the populations in this study was motivated by the high injury rate among the workers and their long work duration in underground mines so that they have good knowledge on the job and working conditions, which allows to properly capture their occupational exposures. The annual rate of injury of 14.9% in the case of French miners was very high compared with that in the case of French construction workers (10%) and that in the case of the French working population from the general compensation system (17.2 million workers, 4.3%) [31]. The participation rate was high, both for Indian miners (100%) as well as for French miners (74%). The narrow age range for French miners resulted from an early age of retirement for workers from that sector (48 years old).

The annual injury rate of 14.9% for French coalminers was also very high compared to the annual injury rate of only 5.5% for Indian coalminers. The reasons for this difference in injury rates between the French and Indian

Table 6. Associations between occupational and personal health-related factors among Indian coalminers

Factors	Cases OR (95% CI)				Controls OR (95% CI)			
	current smoking	sleep disorders (< 6 h)	regular alcohol use	chronic disease	current smoking	sleep disorders (< 6 h)	regular alcohol use	chronic disease
Age < 45 (N = 116)								
hand tool-related	0.69 (0.22–2.10)	**2.94*** (1.23–6.99)	1.85 (0.78–4.34)	**2.33**** (1.03–5.26)	1.71 (0.57–5.09)	0.81 (0.31–2.07)	0.43 (0.15–1.23)	1.04 (0.38–2.84)
material handling	1.45 (0.52–3.97)	0.78 (0.36–1.69)	0.67 (0.30–1.46)	1.36 (0.64–2.87)	1.02 (0.40–2.59)	1.18 (0.56–2.49)	0.90 (0.44–1.84)	0.64 (0.28–1.46)
machine-related	0.83 (0.30–2.28)	0.61 (0.29–1.32)	1.13 (0.52–2.46)	0.66 (0.31–1.39)	1.24 (0.49–3.18)	**2.94**** (1.39–6.06)	1.19 (0.57–2.47)	0.79 (0.34–1.82)
environment/work conditions	1.09 (0.35–3.34)	0.98 (0.43–2.23)	**3.26**** (1.41–7.54)	**2.47*** (1.09–5.60)	1.11 (0.49–2.50)	0.99 (0.53–1.86)	1.03 (0.56–1.89)	0.87 (0.45–1.68)
geological/strata control	0.86 (0.31–2.37)	1.40 (0.64–3.02)	0.83 (0.37–1.83)	0.67 (0.31–1.43)	1.09 (0.49–2.39)	0.88 (0.48–1.64)	0.85 (0.47–1.55)	0.91 (0.47–1.74)
electrical equipment	1.27 (0.37–4.31)	1.16 (0.45–3.0)	**2.97**** (1.15–7.69)	0.56 (0.22–1.44)	0.75 (0.24–2.33)	0.52 (0.23–1.15)	1.39 (0.63–3.06)	0.93 (0.38–2.24)
haulage	0.28 (0.03–2.25)	1.80 (0.65–4.95)	**2.95*** (1.06–8.26)	0.55 (0.20–1.52)	0.15 (0.02–1.17)	0.57 (0.25–1.25)	1.50 (0.67–3.33)	0.79 (0.31–1.99)
blasting	0.45 (0.09–2.15)	1.66 (0.66–4.19)	**4.23**** (1.62–11.0)	**3.10*** (1.19–8.06)	0.56 (0.16–2.02)	0.75 (0.33–1.73)	1.15 (0.51–2.61)	0.66 (0.25–1.75)
Age ≥ 45 (N = 129)								
hand tool-related	**5.00*** (1.41–17.6)	0.91 (0.41–2.02)	0.91 (0.39–2.13)	0.45 (0.20–1.01)	1.32 (0.40–4.37)	1.75 (0.49–6.52)	0.47 (0.17–1.28)	0.86 (0.31–2.38)
material handling	0.89 (0.40–1.95)	**2.21*** (1.06–4.60)	0.74 (0.35–1.59)	0.85 (0.42–1.71)	1.26 (0.45–3.53)	1.33 (0.49–3.56)	0.68 (0.31–1.51)	0.68 (0.31–1.51)
machine-related	1.30 (0.59–2.85)	**3.09**** (1.48–6.45)	1.60 (0.75–3.42)	1.49 (0.74–2.99)	1.03 (0.39–2.70)	0.92 (0.39–2.15)	1.11 (0.54–2.17)	1.03 (0.48–2.21)
environment/work conditions	0.83 (0.35–1.93)	1.58 (0.75–3.40)	0.72 (0.31–1.68)	**3.02**** (1.35–6.71)	1.93 (0.76–4.98)	1.28 (0.58–2.80)	1.10 (0.57–2.12)	1.17 (0.58–2.35)
geological/strata control	0.93 (0.40–2.11)	0.51 (0.23–1.12)	1.45 (0.66–3.15)	**2.63**** (1.23–5.61)	0.84 (0.33–2.14)	0.87 (0.39–1.94)	1.53 (0.78–2.99)	1.21 (0.59–2.48)

electrical equipment	**3.08*** (1.09–8.69)	3.35 (1.39–8.11)	0.96 (0.42–2.17)	0.75 (0.35–1.62)	1.26 (0.45–3.53)	1.33 (0.49–3.56)	0.80 (3.64–1.76)	1.34 (0.59–3.03)
haulage	0.86 (0.34–2.15)	1.97 (0.52–2.71)	1.27 (0.52–3.05)	0.67 (0.30–1.50)	0.75 (0.24–2.41)	1.57 (0.55–4.51)	0.92 (0.41–2.05)	1.81 (0.80–4.12)
blasting	0.86 (0.34–2.15)	2.07 (0.87–4.93)	0.73 (0.31–1.66)	0.57 (0.25–1.28)	0.91 (0.31–2.66)	1.39 (0.52–3.73)	0.75 (0.34–1.64)	1.50 (0.67–3.34)

OR – crude odds ratio; CI – confidence interval.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Bold types: significant factors.
The crude odds ratios were computed using logistic models for each age group and for cases and controls separately by considering each personal factor as explained variable.

Table 7. Associations between biomechanical and physical exposures and personal factors among French coalminers

Factors	Biomechanical exposure score OR (95% CI)				Physical exposure OR (95% CI)
	0	1–4	5–7	≥ 8	
Age < 40 (N = 293)					
current smoking	1.00	1.41 (0.70–2.83)	1.50 (0.73–3.10)	1.11 (0.55–2.22)	0.96 (0.57-1.61)
alcohol misuse	1.00	3.44 (0.71–16.6)	3.21 (0.63–16.1)	**5.20*** (1.13–23.8)	1.01 (0.45-2.29)
obese	1.00	0.78 (0.27–2.30)	0.83 (0.27–2.54)	0.81 (0.28–2.32)	0.96 (0.42-2.19)
not-good health status	1.00	0.58 (0.29–1.15)	1.28 (0.63–2.59)	1.24 (0.64–2.42)	0.89 (0.53-1.48)
chronic disease					
musculoskeletal	1.00	1.79 (0.87–3.67)	**2.90**** (1.38–6.11)	**3.10**** (1.53–6.28)	1.03 (0.62-1.71)
others	1.00	0.88 (0.39–1.95)	1.31 (0.59–2.90)	1.51 (0.71–3.19)	1.18 (0.66-2.11)
psychotropic drug use	1.00	1.56 (0.69–3.54)	1.42 (0.60–3.35)	**2.76**** (1.26–6.05)	1.54 (0.86-2.78)
physical disability (score ≥ 1)[a]	1.00	0.56 (0.16–1.93)	0.84 (0.25–2.75)	**4.40**** (1.69–11.4)	**5.09**** (1.76-14.7)
seeing disability	1.00	1.44 (0.34–6.01)	2.79 (0.72–10.9)	2.05 (0.53–7.92)	2.43 (0.81-7.25)
hearing disability	1.00	0.59 (0.22–1.55)	0.82 (0.32–2.15)	0.81 (0.33–2.01)	1.31 (0.61-2.81)
cognitive disability (score ≥ 1)[a]	1.00	0.74 (0.34–1.65)	1.56 (0.72–3.38)	1.52 (0.73–3.17)	0.90 (0.52-1.56)
self-reported personality traits					
sociable	1.00	0.74 (0.38–1.46)	**0.38**** (0.18–0.80)	0.96 (0.49–1.88)	1.06 (0.63–1.76)
aggressive	1.00	2.20 (0.43–11.3)	0.85 (0.12–6.21)	2.01 (0.39–10.3)	2.89 (0.64–13.0)
organized	1.00	0.68 (0.34–1.36)	0.63 (0.30–1.30)	0.89 (0.45–1.74)	0.83 (0.50–1.40)

Table 7. Associations between biomechanical and physical exposures and personal factors among French coalminers – cont.

Factors	Biomechanical exposure score OR (95% CI)				Physical exposure OR (95% CI)
	0	1–4	5–7	≥ 8	
Age ≥ 40 (N = 223)					
current smoking	1.00	0.50 (0.24–1.02)	**0.43*** (0.19–0.99)	0.80 (0.38–1.70)	0.63 (0.36–1.10)
alcohol misuse	1.00	1.47 (0.41–5.29)	1.67 (0.42–6.62)	**3.33*** (1.00–11.2)	1.04 (0.44–2.44)
obese	1.00	1.18 (0.44–3.17)	0.79 (0.24–2.61)	1.04 (0.36–3.01)	0.74 (0.34–1.59)
not-good health status	1.00	**2.58*** (1.20–5.13)	1.36 (0.62–3.00)	**2.28*** (1.06–4.92)	1.00 (0.57–1.75)
chronic disease					
musculoskeletal	1.00	**2.72**** (1.31–5.63)	**2.99**** (1.31–6.80)	**8.89***** (3.53–22.4)	1.00 (0.57–1.78)
others	1.00	1.30 (0.61–2.76)	0.96 (0.41–2.28)	1.58 (0.72–3.46)	0.94 (0.52–1.67)
psychotropic drug use	1.00	0.94 (0.43–2.03)	0.86 (0.36–2.06)	1.05 (0.47–2.37)	1.41 (0.76–2.63)
physical disability (score ≥ 1)[a]	1.00	**4.10*** (1.11–15.2)	**8.24**** (2.19–31.0)	**15.23***** (4.23–54.8)	1.35 (0.70–2.63)
seeing disability	1.00	**3.08*** (1.05–9.02)	**4.28**** (1.39–13.2)	**3.92*** (1.31–11.7)	2.06 (0.98–4.31)
hearing disability	1.00	**2.66*** (1.03–6.89)	**3.27*** (1.18–9.01)	**5.60***** (2.15–14.6)	**2.03*** (1.05–3.94)
cognitive disability (score ≥ 1)[a]	1.00	1.13 (0.53–2.38)	1.46 (0.64–3.33)	**2.27*** (1.05–4.93)	1.29 (0.73–2.28)
self-reported personality traits					
sociable	1.00	0.91 (0.45–1.86)	1.60 (0.72–3.54)	0.99 (0.46–2.11)	1.15 (0.66–2.01)
aggressive	1.00	0.81 (0.05–13.2)	1.28 (0.08–21.0)	**11.00*** (1.34–90.1)	2.70 (0.58–12.7)
organized	1.00	0.79 (0.37–1.70)	1.48 (0.66–3.34)	1.15 (0.52–2.50)	0.96 (0.54–1.72)

*$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Bold types: significant factors.
The crude odds ratios (OR) were computed using logistic models by considering each personal factor as explained variable.
[a] Score 1–2 and ≥ 3 were grouped because of small number of subjects.

Table 8. Associations between injury and occupational factors – Indian coalminers

Factors	OR1 (95% CI)	OR2 (95% CI)	Reduction/Increase (%)[a]
Age < 45 (N = 116)			
hand tool-related	4.18** (1.87–9.36)	2.45 (0.65–9.30)	54
material handling	2.03* (1.04–4.00)	2.45 (0.83–7.26)	–41
machine-related	4.62*** (2.39–8.92)	3.55** (1.21–10.41)	30
environment/work conditions	2.26* (1.15–4.34)	2.81* (1.01–7.85)	–44
geological/strata control	1.78 (0.97–3.28)	3.22* (1.10–9.43)	–
electrical equipment	0.54 (0.17–1.77)	0.57 (0.11–2.92)	–
haulage	0.73 (0.27–2.36)	0.72 (0.09–5.87)	–
blasting	2.17 (0.55–8.63)	2.38 (0.30–21.87)	–
Age ≥ 45 (N = 129)			
hand tool-related	1.41 (0.60–3.28)	1.88 (0.57–6.15)	–
material handling	3.96*** (2.00–7.84)	6.23** (2.12–18.3)	–77
machine-related	1.78 (0.96–3.28)	0.87 (0.33–2.25)	–
environment/work conditions	1.99* (1.11–3.59)	4.01** (1.70–9.50)	–204
geological/strata control	2.26** (1.31–3.90)	2.37* (1.10–5.12)	–9
electrical equipment	1.60 (0.63–4.06)	0.67 (0.18–2.41)	–
haulage	0.67 (0.25–1.76)	1.01 (0.24–4.20)	–
blasting	0.91 (0.30–2.78)	0.55 (0.12–2.50)	–

Abbreviations as in Table 4.

Table 9. Associations between injury and occupational factors – French coalminers

Factors	OR1 (95% CI)	OR2 (95% CI)	Reduction/Increase (%)[a]
Age < 40 (N = 293)			
biomechanical exposure (score)			
0	1.00	1.00	
1–4	2.21 (0.86–5.64)	2.99* (1.05–8.52)	–
5–7	3.21* (1.20–8.55)	4.14* (1.34–12.80)	–42
≥ 8	7.19*** (2.75–18.80)	8.76*** (2.90–26.40)	–25
physical exposure	0.77 (0.39–1.52)	0.64 (0.30–1.36)	–
Age ≥ 40 (N = 223)			
biomechanical exposure (score)			
0	1.00	1.00	
1–4	4.28** (1.59–11.50)	3.45* (1.18–10.10)	25
5–7	3.51* (1.19–10.40)	2.48 (0.76–8.07)	41
≥ 8	6.73*** (2.23–20.30)	4.26* (1.16–15.60)	43
physical exposure	0.48* (0.23–0.99)	0.55 (0.25–1.23)	–13

Abbreviations as in Table 4

coal mines, which were under investigation, was due to the fact that the mining conditions were very difficult for the French coalminers compared to the Indian ones. Specifically, it was observed that gradient of the coal seam for the French coal mines varied between 22 and 30 degrees, whereas the gradient of the coal seam for the Indian mines was reasonably flat (varying between 5 degrees to 10 degrees), which made the mining conditions very tough and challenging for the French coalminers. Moreover, in the case of the French coalminers, mining was carried out at a depth of 1250 meters from the surface compared to only 300 m in the case of the Indian coalminers. The difference could be also attributed to other environmental factors (such as nature of ground), materials and processes used, work organization, job knowledge, health status, and unhealthy behaviors which are well known potential injury risk factors [4].

Although the working conditions differed between the Indian and French miners, this study revealed that biomechanical exposure played the main role in occupational injuries. Indeed, among Indian miners who had an annual rate of injury of 5.5%, the 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 the geological/strata control-related hazards were associated with a 2-fold higher risk of injury. The higher risk for the machine-related hazards was consistent with a study in the USA mining industry [32].

Among French miners who had the 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. This pointed the role of cumulative effect of a number of hazards that affected most miners. The injuries were generally directly related to the tasks and those hazards with increasing tiredness or improper posture had higher risks of injury (data not shown) [13]. These findings were expected as most of the miners were exposed to demanding tasks and they always worked in changing hazardous work environment, under freshly exposed roof and on slippery floor conditions. In this context, the experience and job knowledge cannot eliminate the injuries if the number of demanding hazards is continuously high. Thus, prevention should focus especially on those hazards that affect working capacity of the workers and consequently the quality of task performed, alertness, vigilance, and observing numerous hazards [3,33].

Our studies found that, like occupational factors, the personal ones such as regular alcohol use, sleep disorders, altered health status, frequent psychotropic drug use, and chronic diseases (especially musculoskeletal disorders), as well as physical, seeing, hearing, and cognitive disabilities, which may affect working capacity of the workers, also played a role in the injuries. Lack of education, self-reported personality traits, risk-taking behavior, and large family were the other known risk factors [3,4,11,26] identified in our studies. Strong disparities were observed between the Indian and French miners concerning contribution of the studied personal factors to the associations between occupational factors and occupational injuries. Among French miners the effect of personal factors was negligible for low biomechanical exposure (score 1–4: 5%) but was 24% for high biomechanical exposure (score: $\geq$ 8). This finding suggests that when the injury risk associated with occupational hazards is high, personal characteristics have moderate confounding influence on it. It should be noted that, among French miners, the recruitment process is selective and the workers take retirement at a young age (48 years). Moreover, the miners had to work in groups/teams so that the most demanding and challenging tasks were performed by the workers with better abilities due to their solidarity and recommendations of occupational physicians. The workers were not allowed to consume tobacco and alcohol at work, which may have immediate effect on working capabilities [3]. Among Indian miners with much lower injury risk, on the other hand, it was observed that the personal factors had marked contributions, which varied a lot across the types of occupational hazards. They explained about 80% of associations between the hand tool-related and machine-related hazards and injuries, and this finding highlighted the role of lack of education and other factors related to workers' abilities and risk-taking behavior. 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 of this study for the 2 study populations was that the role of occupational hazards in injuries and the interplay of personal factors varied across different age groups. We found that among the Indian miners the hand tool-related and machine-related hazards affected the workers aged < 45, while material handling and geological/strata conditions affected the older miners to a bigger extent. This may point the lack of knowledge, inexperience or lack of risk awareness among the younger workers and a lower physical capacity and a lower perception capacity among the older ones. Experience and job knowledge are acquired through a long period of work, often exceeding 10 years [3,12].

It would be of interest to observe that personal factors exacerbated the risks associated with material handling, environment/work conditions, and geological/strata control among the miners aged ≥ 45; while among the younger miners, personal factors reduced the risks associated with hand tools and machines but increased the risks associated with material handling, environment/work conditions, and geological/strata control. This may suggest that younger age had higher physical capacity to reduce only the risks due to hand tools and machines, while the risks due to material handling, environment/work conditions, and geological/strata control affected all ages and personal factors could just accentuate them and not assist them.

The indirect roles of occupational factors in injuries appeared to be complex. They may generate sleep disorders and chronic diseases which may in turn favor occupational injuries via mental disorders and lower capabilities [3,34] not only among miners aged ≥ 45 but also among the younger age groups.

Tobacco and alcohol consumption was also health-related problem influencing injuries. We found that smoking affected more the subjects aged ≥ 45 while alcoholism affected more the younger age groups. Prevention should take into account these specific characteristics and reduce occupational hazards and health-related issues.

Among the French miners the result was somewhat different. It was observed that biomechanical exposure, scores 5–7 and ≥ 8, were associated with similar risks in the 2 age groups (< 40 and ≥ 40 years), but the risk was high for the score 1–4 for the miners aged ≥ 40 only. Personal factors explained 25–43% of the risks associated with various scores for the miners aged ≥ 40, while they had negative contributions (–42% for scores 5–7 and –25% for score ≥ 8) for the miners aged < 40. Unlike Indian miners, personal factors had opposite contributions to the biomechanical exposure-injury associations for the 2 age groups (41% for scores 5–7 and 43% for score ≥ 8). Regarding physical exposure, it had a protective role only among the miners aged ≥ 40 which was explained by the personal factors.

These findings may be explained by the fact that biomechanical and physical exposures may have modified a wide range of personal factors including alcohol misuse, musculoskeletal disorders, and disabilities among miners aged ≥ 40, which were also observed among younger miners but to a lesser degree. Thus, the injury mechanism is very complex because occupational exposures not only increase the injury risks but also alter personal factors which are also related to injuries depending on the subject's age. High contribution of personal factors to the biomechanical exposure-injury association demonstrates that they may not be adequately taken into account. These findings are important for prevention in the context where more workers may have to continue working in an older age because of higher retirement age.

Our findings are important since we found high roles of occupational activities and work environment in the 2 populations. The part played by personal factors may be seen somewhat as the response of personal characteristics to occupational situations. The fact that the results greatly differed between various age groups is important for our society because of higher retirement age in the years ahead in various countries. The study populations, their occupational activities and work environment, their injury risk level, workers' age and capabilities, as well as workers' socioeconomic contexts may greatly influence the results. Thus, the results obtained on such a population cannot be easily extrapolated to other populations, and may need to be confirmed by other studies. The literature on the role of workers' age in injuries is abundant [2–4,12,35–39], but studies have neither addressed occupational factors or exposures nor personal factors. Our work which combined 2 surveys in different countries using different methodological approaches may give substance to our objective to show that prevention in order to reduce injuries should consider workers' capabilities even when the occupational activities, working conditions and the injury risks are different.

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 definition of the considered occupational injuries was similar for the 2 studies (injuries with sick leave). The Indian survey used a face-to-face interview performed by a trained personnel while the French survey was conducted through a self-administered questionnaire. However, these procedures are common in epidemiological studies. These measure tools were also used in other studies [3,11,18,25]. The occupational and personal factors were different between the 2 surveys. This may correspond to the study populations. Occupational exposures were reported by the subjects. They concerned the period of time before and around occurring of the injury. Smoking and alcohol misuse were generally persistent and started from adolescence or young adulthood [3]. Chronic diseases were limited to those that had been diagnosed by a physician. The Indian and French miners were not of similar age because of the young age of retirement in the case of French miners. The considered age groups were a bit different for the 2 studies. However, these age groups were chosen to reach a maximum power for statistical tests for each age group. The age thresholds – 40 or 45 years – approximately correspond to the beginning of physical and mental disabilities in general population [40,41].

Given the large number of the carried out statistical tests, type I error may be a concern, but it has to be pointed that most tests were significant at the 0.01 level, with very large odds ratios estimates. Finally, we showed convergent interplays between occupational and personal factors even using different statistical approaches just as generally it has been done in various studies in the literature.

CONCLUSIONS

This study demonstrates that Indian and French coalminers were exposed to a number of occupational hazards, which played high roles in occupational injuries. Personal factors had a modest confounding role in French miners. Among Indian coalminers with much lower injury risk, a high role was found for material handling, environment/work conditions and geological/strata control, and their roles were higher when controlling for personal factors in the miners aged ≥ 45. In the younger miners the interplay of occupational and personal factors depended on the hazards.

Potential occupational hazards played high roles and the interplay of personal factors differed between the studied populations, occupational activities, injury risk level, workers' age, and workers' socio-economic contexts. Over career occupational hazards may also alter personal factors such as health-related factors. The extrapolation of the results from the study population to other populations may need to be confirmed by other studies. This knowledge may be useful to understand the injury mechanisms when designing prevention programs aiming at reduction of occupational injuries across various age groups. Further studies are needed to confirm these findings in other populations.

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