ORIGINAL ARTICLE

Individual characteristics in occupational accidents due to imbalance: a case-control study of the employees of a railway company

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Background: Falls are frequent occupational accidents, and are responsible for a significant amount of lost working time and, more importantly, for a high mortality. The factors involved in falling mechanisms can be of external or individual origin, the latter being less well identified.
Aims: To assess the relations between certain individual characteristics and occupational accidents due to imbalance.
Methods: A total of 427 male employees, who had been victims of at least one occupational accident with sick leave due to imbalance (cases) and 427 controls were recruited among the employees of a large French railway company. A standardised questionnaire on life conditions and professional factors, and a description of the accidents was filled in by an occupational physician for each subject.
Results: Some job categories were more affected by a specific release mechanism of work related falls. Certain individual characteristics such as smoking, alcohol consumption, inactivity, sleep disorders, and request for a job change were correlated with the occurrence of occupational accidents. Sick leaves of eight days or over were more frequent in older and overweight injured workers. Some lesions were linked with the specific fall released mechanisms.
Conclusions: Individual characteristics can increase the risk of occupational accidents, especially falling. This study identified subjects most at risk on whom prevention related to working conditions and falls could be focused.

Accidents are a major public health problem. Among the 120 million occupational accidents occurring each year in the world, 210 000 are fatal.[1] Occupational accidents are frequent in France[2]; of these, for all sectors of industries combined, 20–25% are due to falls,[3] this rate reaching 33% in some sectors.[4] These types of occupational accidents, which result mainly in sprains and fractures,[5 6] can lead to sick leave due to disability, the length varying with age.[7] In France, 22% of lost working time is due to falls.[8] Falls represent 2% of fatal accidents in France,[8] 10% in the USA,[9] and 26.9% in Japan.[10] Moreover, in the USA, falling is the fourth major cause of fatal accidents.[9 11] Work related falls are more frequent in women than in men,[7 11–12] and increase with the age of workers.[4 11 12]

Falls occur more often during normal gait, and 50% take place on work premises.[13] Different studies on the step and its interactions with the ground have shown that the main component responsible for falls was an unexpected event between the foot and its support, and that slips and trips were important contributory factors.[5 13] Therefore, falling is generated when balance regulating mechanisms are surpassed by the extrinsic or intrinsic origin destabilisation. In terms of balance, postural control can be defined as a complex sensorimotor function requiring the central integration in the vestibular nuclei of information from multiple sensory afferences (visual, vestibular, and somatosensory) leading to the selection and execution of context specific motor responses.[14] In normal conditions (stable vision, fixed support), this neurosensorial information is redundant, but complementary, with a higher contribution of proprioceptive and visual inputs than vestibular ones.[15] Balance function applies to gaze stabilisation by the vestibulo-ocular reflex and to posture stabilisation by the vestibulo-spinal reflex. Postural regulation dysfunction at the informative, integrative, or motor level caused by external or internal factors can generate imbalance and finally a fall, the human and financial repercussions of which can vary in seriousness according to age and to the work environment and conditions.[16 17]

Several factors inducing imbalance and the risk of falling have been identified. While the extrinsic factors are well known—that is, those concerning the occupational environment and organisation, including the type of floor, shoe, and their interactions,[5 6 13 17–20] lightning,[18] temperature,[21] and the activity itself,[13] few authors have investigated the relation between individual factors and work related falls. Apart from the diseases provoking balance troubles, it has been shown that imbalance and the risk of falling are increased by factors such as age,[16 22] alcohol consumption,[23–25] smoking,[26–28] fatigue,[29 30] and sleep disorders.[31] Moreover, it seems that physical and sporting activities can limit imbalance and the risk of falling,[32 33] as cab or workplace experience,[34] and the subject's attention.[35]

Occupational accidents with sick leave are a major issue for the French National Society of Railway (SNCF), the annual frequency rate being almost 40 accidents per 1000 employees. Moreover, falls represent more than 15% of the total number of accidents. The aim of this study was to determine whether certain individual characteristics of employees influence the occurrence of occupational accidents due to imbalance.

MATERIAL AND METHODS

Subjects

This survey was a case-control study conducted on voluntary male employees from 23 SNCF establishments in different regions of France. The cases were recruited by occupational physicians at the consultations before the return to work after an occupational accident. The controls were also recruited by the occupational physicians at the yearly medical examinations.

The cases were male employees who had worked for three years or more in the company and who had been victims of at

Table 1 Distribution according to the job category of the injured employees (%)

	Slip* (130 subjects)	Disequilibrium, trip, collision with a moving vehicle (227 subjects)	Bad landing on the floor (70 subjects)	Total (427 subjects)
Commercial employees				
Travelling ticket inspectors	3.1	8.4	8.6	6.8
Other jobs	6.2	4.4	0.0	4.2
Conception, construction, maintenance				
Mechanical maintenance operators	23.1	11.5	11.4	15.0
Railway maintenance operators	12.3	9.7	12.9	11.0
Other jobs	6.9	10.6	8.6	9.1
Transport production, shunting, circulation, and logistics				
Production operators	10.0	12.8	15.7	12.4
Circulation operators	7.7	11.9	7.1	9.8
Other jobs	8.5	5.7	10.0	7.3
Train drivers	13.1	11.5	20.0	13.3
Other jobs	9.2	13.7	5.7	11.0

The independence χ^2 test applied to the overall contingency table was significant ($p<0.05$).
*Slips were more frequent in the mechanical maintenance operators than in the other subjects (46.9% *v* 27.5%, $p<0.01$).

least one occupational accident with sick leave due to imbalance between 1 March 1999 and 29 February 2000 (12 months). Fatal accidents were excluded (there was during 1999, for all the staff of the SNCF, only one fatal accident due to a fall during going down from the train). The controls were also male employees who had worked for three years or more in the company, but who had not had an occupational accident with sick leave over the course of the preceding three years.

One control with the same job and from the same establishment was matched to each case, and was the first subject examined by the same occupational physician satisfying the selection criteria. It should be noted that, among the subjects contacted, one only refused. In total, 427 cases and 427 controls were recruited. Thirteen cases without controls were eliminated. The time interval between the recruitment of a case and that of the corresponding control was relatively small (zero values 11%, geometric mean (SD) of values different from zero, 35 (4) days). The delay was mainly due to the matching criteria.

Study design

The survey used a standardised questionnaire, filled in by the occupational physician in the presence of the subject. It comprised date of birth, weight, height, type of job, duration in present job, work environment change (physical environment and/or activities), job satisfaction defined by "request for a job change", smoking habits, alcoholic drink consumption (nearly every day), sporting activities, sleep disorders (defined by less than six hours of sleep per day, "sleeping badly", or regular consumption of sleeping pills), and a description of the accidents for the cases. The factors considered concerned the period of the accident occurring for the cases and the period of interview for the controls. For each pair (case and control), the questionnaires were filled in by the same occupational physician.

The present survey was approved by the Commission Nationale de l'Informatique et des Libertés. The subjects involved had previously been informed of the objectives of the study, and had given their written informed consent.

Statistical analysis

The accidents were grouped into three categories: 1, slip; 2, disequilibrium, trip, collision with a moving vehicle; and 3, bad landing on the floor (when getting out of a vehicle). The quantitative variables, namely age, years in the current job, and number of hours of sleep per day were divided into two classes. To assess the relations of the various factors with the accidents, crude odds ratios, 95% confidence intervals, and

Table 2 Relations between the various factors and occupational accidents: crude and adjusted odds ratios and 95% confidence intervals

	Slip (130 subjects)	Disequilibrium, trip, collision by a moving vehicle (227 subjects)	Bad landing on the floor (70 subjects)	Total (427 subjects)
	Crude odds ratios [95% CI]			
Age ⩾50 years	1.00 [0.43 to 2.34]	1.21 [0.68 to 2.17]	1.00 [0.13 to 7.47]	1.13 [0.72 to 1.77]
Body mass index ⩾30 kg/m^2	1.13 [0.53 to 2.44]	1.33 [0.76 to 2.37]	1.10 [0.42 to 2.89]	1.22 [0.83 to 1.82]
Sleep disorders	1.29 [0.70 to 2.39]	1.56* [1.00 to 2.52]	0.85 [0.34 to 2.05]	1.33 [0.96 to 1.86]
Current smoker	2.06** [1.14 to 3.84]	1.49* [1.00 to 2.27]	1.27 [0.61 to 2.68]	1.58*** [1.17 to 2.14]
Alcoholic drink consumption: nearly every day	1.09 [0.44 to 2.73]	1.31 [0.65 to 2.69]	4.00* [1.08 to 22.10]	1.50 [0.92 to 2.47]
No sporting activity	1.96** [1.17 to 3.35]	1.59* [1.04 to 2.47]	2.56** [1.14 to 6.28]	1.84*** [1.37 to 2.50]
No do-it-yourself and gardening activities	1.32 [0.73 to 2.41]	1.20 [0.75 to 1.96]	2.80* [1.00 to 9.93]	1.38 [0.98 to 1.95]
One year or less in present job	0.40 [0.04 to 2.44]	1.80 [0.54 to 6.84]	0.25 [0.01 to 2.53]	0.86 [0.36 to 2.00]
Frequent change of work environment	0.67 [0.31 to 1.37]	1.09 [0.67 to 1.77]	1.08 [0.46 to 2.60]	0.96 [0.67 to 1.36]
Request for a job change	1.30 [0.53 to 3.31]	2.07* [1.08 to 4.12]	2.50 [0.72 to 10.90]	1.86** [1.16 to 3.03]
	Adjusted odds ratios [95% CI]†			
Current smoker	1.93* [1.08 to 3.43]	1.52* [1.01 to 2.28]	–	1.53** [1.13 to 2.07]
Alcoholic drink consumption: nearly every day	–	–	6.17* [1.36 to 28.0]	–
No sporting activity	1.86** [1.12 to 3.07]	1.63* [1.07 to 2.48]	3.15* [1.25 to 7.93]	1.83*** [1.35 to 2.48]
No do-it-yourself and gardening activities	–	–	4.20* [1.29 to 13.7]	1.42* [1.00 to 2.01]
Request for a job change	–	2.31** [1.23 to 4.35]	4.23* [1.03 to 17.4]	1.94** [1.21 to 3.11]

*p<0.05, **p<0.01, ***p<0.001.
†Calculated with conditional logistic regression for paired data. No significant adjusted odds ratio was found for age, sleep disorders, one year or less in present job, and frequent change of work environment.

Table 3 Relations between the various factors and sick leave of eight days or more: adjusted odds ratios and 95% confidence intervals calculated with logistic regression method

	Adjusted odds ratios [95% CI]
With all the factors in the regression model	
Age ⩾50 years	1.95* [1.04 to 3.63]
Body mass index ⩾30 kg/m^2	2.07* [1.03 to 4.16]
Sleep disorders	1.30 [0.78 to 2.17]
Current smoker	1.44 [0.91 to 2.27]
Alcoholic drink consumption: nearly every day	1.46 [0.70 to 3.04]
No sporting activity	1.07 [0.67 to 1.72]
No do-it-yourself and gardening activities	1.03 [0.66 to 1.61]
One year or less in present job	0.86 [0.28 to 2.63]
Frequent change of work environment	1.07 [0.68 to 1.69]
Request for a job change	0.88 [0.48 to 1.64]
With stepwise forward procedure retaining only significant factors (p<0.05)	
Age ⩾50 years	1.84* [1.01 to 3.35]
Body mass index ⩾30 kg/m^2	2.08* [1.05 to 4.11]

*p<0.05.

McNemar's χ^2 test for matched data[36 37] were computed. Adjusted odds ratios were then calculated using conditional logistic regression (for paired data) with the stepwise backward procedure.[36] The logistic regression method was used to examine the roles of the factors considered in sick leave of eight days or more in the injured subjects.[36] All analyses were performed with the Stata[36] and Epi Info[37] programs.

RESULTS

The samples included 427 cases and 427 controls. Mean age was 41.4 (SD 7.3) years for the cases and 41.1 (SD 7.2) years for the controls (non-significant difference). Among the cases, 13.8% were aged 50 or over, 26.0% had sleep disorders, 40.3% were current smokers, 12.2% declared having consumed alcohol nearly every day, 58.1% practised no sporting activity, and 30.2% did no do-it-yourself or gardening activities. Regarding occupational conditions, 3.7% of the cases declared being in their present job for one year or less, 39.1% stated that their work environment frequently changed, and 14.5% had requested a job change.

Table 1 shows that the accidents studied affected all main job categories. Slight, but significant differences were noted between job categories ($p < 0.005$). The slips mainly concerned the mechanical maintenance operators, and the bad landing on the floor mainly concerned the train drivers, production, and railway maintenance operators.

Table 2 gives the crude and adjusted odds ratios for the various risk factors considered. The factors having significant adjusted odds ratios for all accidents combined were: current smoker, no sporting activity, no do-it-yourself and gardening activities, and request for a job change. For slips, only current smoker and no sporting activity had significant adjusted odds ratios. Concerning disequilibrium, trip and collision with a moving vehicle, these two factors were also found to be significant, as well as request for a job change. Regarding bad landing on the floor, the factor with the highest adjusted odds ratio was alcoholic drink consumption, followed by request for a job change, no do-it-yourself and gardening activities, and no sporting activity. However, interpretation of these results needs to be cautious due to the small number of subjects.

Among the injured subjects, sick leaves of eight days or more were more frequent in older subjects (50 years or over) and in overweight workers (body masss index (BMI) ⩾30 kg/m^2) (table 3).

Table 4 Distribution of occupational accidents due to disequilibrium according to lesion and sick leave length

	Slip (130 subjects)	Disequilibrium, trip, collision with a moving vehicle (227 subjects)	Bad landing on the floor (70 subjects)	Total (427 subjects)	Test
Lesions					
Contusions, haematoma	26.2	28.6	10.0	24.8	p<0.01
Sprains, dislocations	44.6	56.4	74.3	55.7	p<0.0005
Spine attack	10.0	6.6	10.0	8.2	NS
Cut	11.5	6.6	2.9	7.5	NS
Strained, torn or pulled muscle, tendon, or ligament	13.1	10.6	8.6	11.0	NS
Fractures	11.5	10.6	1.4	9.4	p<0.05
Other pathologies	5.4	7.5	4.3	6.3	NS
Locations					
Head and neck	3.8	4.4	5.7	4.4	NS
Trunk and hip	13.1	12.3	7.1	11.7	NS
Hand, finger, wrist	5.4	5.3	4.3	5.2	NS
Other locations of upper limb	5.4	4.8	2.9	4.7	NS
Ankle	34.6	39.6	57.1	41.0	p<0.01
Other locations of lower limb	26.9	26.9	20.0	25.8	NS
Sick leave length (days)					
⩽7	36.9	27.6	22.1	29.5	
8–14	24.6	27.6	23.5	26.0	NS
⩾15	38.5	44.7	54.4	44.5	
Hospitalisation	4.6	6.6	7.1	6.1	NS

Table 4 presents the distribution of the accidents according to lesion, duration of sick leave, and hospitalisation. For all accidents combined, sprains and dislocations represented about 55.7%, contusions and haematoma 24.8%, strained, torn, or pulled muscles, tendons, or ligaments 11.0%, and fractures 9.4% of the cases. Sprains and dislocations were the most common lesions in the cases of bad landing on the floor, and to a lesser degree, of slipping, disequilibrium, trip, and collision with a moving vehicle ($p < 0.0005$). Contusions and haematoma, and fractures were less represented among the accidents due to bad landing on the floor ($p < 0.01$ and $p < 0.05$ respectively). The lesions mainly concerned the ankle (41.0%) and other parts of the lower limbs (25.8%). About half of the accident victims had sick leaves of 15 days or more, and 6.1% required hospitalisation. There was no significant difference between the three causes of accidents in relation to duration of sick leave and hospitalisation.

DISCUSSION

The present case-control study shows that, although the accidents studied affected all main job categories, some were more affected by a specific release mechanism of work related falls. Moreover, some factors related to living conditions and lifestyle such as age, sleep disorders, smoking habits, consumption of alcohol, sporting activities, do-it-yourself or gardening activities, and request for a job change were correlated with the occurrence of occupational accidents and sick leave length. Let us recall that the factors considered concerned the period of the accident occurring for the cases and the period of interview for the controls. Finally, it would appear that lesions caused by accidents are linked with the specific release mechanisms.

It should be noted that, in this study, the definition of alcohol consumption did not concern an excess of consumption, but also included moderate consumption. Moreover, the BMI was determined at the time of interview and not at the time of the accident for the cases. We believe that it did not greatly vary between the two periods for most workers as only 16.2% of them had sick leaves of more than 31 days. Furthermore, nearly all the injured subjects had not been hospitalised or had a disability due to the accidents, and most had returned to work at the time of interview. It would be possible to use the BMI at the previous yearly medical examination, but the time interval from then until occurrence of the accident was too great (between one day and 12 months).

Although the study was conducted on a large sample, the number of accidents gathered was relatively small, especially for those caused by bad landing on the floor. This results in particular in a lack of power for statistical tests. Interpretation of the results therefore has to be cautious.

Concerning the relation between accidents and job categories, this study shows that slips mainly concerned the mechanical maintenance operators, and bad landing on the floor mainly the train drivers and, to a lesser degree, production operators. This result seems to be consistent as it corresponds to the work conditions of the employees. The category of mechanical maintenance operators concerns all employees who work in the workshops, and on the railway line or platform. The ground or floor is often wet or dirty due to the presence of oil or dust, and several assessments have shown the role of contaminants in the generation of slips.[5 19] The second category presented here primarily concerns train drivers. The specific feature of this job is that the driver remains in the same position, seated in the cab, throughout the journey. Descending from the vehicle by stairs or steps is a complex locomotor task, which involves highly eccentric muscle action at both the knee and ankle,[38] as well as the somatosensory function.[39] On account of the long period in the same posture, a modification of muscular activation and somatosensory control can occur and generate muscular response disorders, leading to a bad landing on the floor and thus a fall.

The second important point to emerge from this study is the relation between individual living conditions and lifestyle and the different release mechanisms of work related falls. The first lifestyle parameter involved here is smoking, particularly on slipping and disequilibrium, and on tripping and striking by a moving vehicle. Smoking affects physical functions, particularly balance[27] and the integrative functions.[26] Gaze and posture stabilisation are particularly affected by nicotine due to its effects on the vestibulo-ocular and vestibulo-spinal reflexes.[28] By acting on integrating and motor levels of postural regulation, smoking impairs balance reactions due to a destabilising event such as slipping or tripping, and could also cause falling.

Another lifestyle parameter involved in falls is alcohol consumption, in particular its relation with bad landing on the floor. Certain assessments have shown the relations between alcohol, accident, and mortality,[40] whereas others have evaluated the effects of alcohol consumption on postural control and movement.[23–25 41] The latter suggest that alcohol primarily affects two sites of balance and movement regulation, namely the inner ear in acute alcoholism,[41] and the vestibular nuclei[24] and cerebellum in chronic alcoholism.[23 25] The cerebellum has an essential coordinating function in the stabilisation and orientation mechanisms during and after a task acquisition process.[42] In this case, descending from a vehicle is an extremely challenging locomotion task, and is even more dangerous outside the station on the open line where there is a significant difference in level between the cab and the track. This complex task, the aim of which is to put feet on an irregular surface, requires good coordination. Vestibular nuclei and cerebellum attack by chronic alcoholism can induce a conflict between dynamic balance and movement, and so provoke falls.

Sleep disorders and requesting a job change are two life condition parameters which can also generate occupational accidents. Both factors can influence vigilance, but their mechanisms are different. Sleep disorders act on vigilance by the fatigue induced, whereas requesting a job change is mainly a cognitive process. In every case, these two factors are involved in generating falls through tripping, disequilibrium, or collision with a moving vehicle. These fall release mechanisms have in common the presence of an event or object which unbalances the worker. The role of vigilance is well known in task execution and postural regulation.[34 43] Lack of attention, distraction, or dual task activity modifies the efficiency of task execution or motor response,[43] and increases the probability of tripping.[44] It does not allow the worker to avoid obstacles and anticipate destabilisation; postural adjustments are therefore reactional, and are thus likely to be insufficient to regulate posture and can lead to falling.

Finally, this study confirms that inactivity is correlated with fall release mechanisms, and that sporting activities and, to a lesser degree, do-it-yourself and gardening activities, could prevent occupational accidents. Physical activities, particularly sport and physical training, are known to increase the quality of postural control,[31 32 45] by developing neurosensorial information sensitivity, particularly somatosensory and vestibular sensitivity, and by increasing central integration efficiency—that is, by faster treatment, better selection of relevant information, and a more appropriate motor response; this promotes anticipatory postural adjustments. Practising physical activity allows faster detection of destabilisation and the organisation of compensatory mechanisms to avoid accidents.

Another important point is the correlation study between individual characteristics and sick leave length. First, even if this study does not confirm the increased risk of accidents occurring in older workers,[4 11 12] it confirms the fact that sick leave length varies with age.[7] This study highlights the fact that an age of over 50 is correlated with more prolonged sick leave. Many reasons could be advanced, especially those in

Main messages

- Falls are one of the most important causes of occupational accidents.
- Some individual factors such as smoking, alcohol consumption, inactivity, sleep disorders, and request for a job change play a role in the occurrence of falls.
- Longer sick leaves are more frequent in workers aged 50 or over and in overweight individuals.
- Specific release mechanisms of work related falls are dependent on the nature of the job and generate specific lesions.

Policy implications

- Knowledge of individual characteristics would allow understanding of the mechanisms of falls with both environmental and organisational factors.
- Individual characteristics should be taken into account in the prevention of work related falls because of their interactions with extrinsic factors.

relation to physical recovery and to psychological and social consequences. In older individuals, physical recovery seems to be longer than in younger ones.[46 47] Moreover, several psychological sequelae could be present after an accident,[48 49] even despite relatively minor physical injuries.[48] Second, longer sick leave is associated with overweight workers. To our knowledge, no study has been interested to the relation between overweight and sick leave. One study has shown that obesity leads to an increased risk of falling,[50] particularly because of the difficulty in controlling balance recovery in the anterior position, but sick leave length was not studied. Our results suggest that accidents may be more severe in overweight workers.

Finally, the consequences of work related falls mainly seem to be sprains and dislocations, contusions and haematoma, and fractures. Sprains, particularly at ankle level, are the most represented lesions in the case of bad landing on the floor, and to a lesser degree, of slipping, disequilibrium, tripping, and collision with a moving vehicle. Biomechanical analysis of stair descent indicates a relative dominance of the ankle as the most important joint.[38] Here, an analogy could be made, and would explain the relative importance of ankle injuries. In non-sporting individuals the ankle muscles are weaker than in those practising sports.[33] This can generate sprains if destabilisation leads the foot in a non-physiological axis.

In conclusion, knowledge of individual life conditions and lifestyle has to be taken into account in the prevention of occupational accidents, and particularly of work related falls. It should be borne in mind that environmental and organisational factors are not the only ones responsible for falling. Individual factors, even if they are less known and more difficult to evaluate, are also important.

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ECHO

Short sight is an eye opener for workers in pneumatic caissons

Please visit the Occupational and Environmental Medicine website [www.occenvmed.com] for link to this full article.

Construction workers operating in great depth pneumatic caissons should be monitored carefully by occupational health services for signs of short sight, concludes an ophthalmological study in Japan.

Among 12 caisson workers aged 22–57 years, nine stated their distance vision was blurred and three of them had eye pain or itching Eight actually had short sight, and seven were considered to have short sight of late onset.

The researchers estimated the time to onset of symptoms as 4–30 work sessions (346–2407 minutes) and the total period of exposure to oxygen during that time as 18–44 sessions (1269–3833 minutes, total oxygen exposure 5628–17 745 UPTD (unit of pulmonary toxicity dose). On re-examination six months later short sight had resolved in most men and increased in one. The researchers calculated the workers were exposed to partial pressure of oxygen of 1.2–1.5 atmospheres absolute pressure (ATA), lower than routinely used in hyperbaric oxygen treatment.

The workers had been working for 11 weeks maintaining machinery in the caisson, working for 29–119 minutes at 4.15–4.75 ATA, 4 days a week (men × sessions = 524) before having a thorough eye examination. All except three were examined again six months after the job had finished.

Great depth engineering is a new method whose use is spreading rapidly with the demands of large scale civil engineering projects. Under Japanese law workers in high pressure environments must be monitored for medical conditions, but eye problems have not been mentioned before.

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