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Effect of Joint Exposure to Psychosocial and Physical Work Factors on the Incidence of Workplace Injuries: Results From a Longitudinal Survey

Régis Colin ^{1,2} Pascal Wild ² Christophe Paris ¹ Stéphanie Boini ²

1 Irset - Institut de recherche en santé, environnement et travail

2 INRS (Vandoeuvre lès Nancy) - Institut national de recherche et de sécurité (Vandoeuvre lès Nancy)

**Effect of joint exposure to psychosocial and physical work factors on the incidence of workplace injuries:
Results from a longitudinal survey.**

Abstract:

Objective: To analyze the interaction between physical and psychosocial work factors regarding the workplace injuries incidence among 6900 workers out of a longitudinal survey.

Methods: Based on responses to questionnaires, we obtained exposure groups respectively for physical factors and for psychosocial factors using hierarchical clustering. We performed multiple Poisson regression model with the workplace injuries incidence during four years of follow-up as the outcome and the clusters as the independent variables of interest.

Results: High psychosocial exposure had a deleterious effect on workplace injuries incidence, which was no longer significant when adjusting for physical factors. The difference in model-based workplace injuries rates between high and low psychosocial exposures seemed to increase (non-significantly) with increasing physical exposure.

Conclusions: The risk of workplace injuries was highest among workers with high physical exposures regardless of the psychosocial exposures.

Keywords: Workplace injuries. Psychosocial factors. Physical factors. Joint exposure. Longitudinal survey.

Introduction

Despite many efforts to improve occupational health and safety prevention, many workplace injuries still persist and lead to sick leave and even death. Although the number of workplace injuries is lower nowadays than 20 years ago, they are still numerous ^{1,2}. The average annual number of workplace injuries per 1,000 employees showed a strong overall decline followed by a slow-down since the early 2000 (118 in 1955, 40 in 2000, 38 in 2008 and 34.5 in 2018), but with marked sectorial differences. In France in 2018, the number of workplace injuries increased by 2.9% compared to 2017, particularly in personal assistance, transport and construction activities ². Workplace injuries cause physical as well as psychological harm, generate costs for workers, employers and society, and thus remain a current concern. Physical exposures to heavy loads, repetitive tasks, and uncomfortable postures decreased between 1994 and 2017, contrary to the exposures to the noise or vibrations ³. Despite the implementation of preventive occupational health and safety plans in France, physical occupational risks remained high in 2017: almost half of employees were exposed to at least one physically demanding working condition and one quarter was exposed to multiple physically demanding constraints ⁴. These physical exposures were part of an organizational context that was still very constrained ³. Work intensity has increased over the past 20 years, although it stabilized between 2010 and 2017. Even if the procedural autonomy of workers decreased between 2003 and 2017, the workers have reported more opportunity to perform high-quality jobs. Since 2010, exposure to jobstrain has stabilized at a high level and the gaps between the different categories of workers have widened regarding the lack of reward. In summary, although the working conditions have evolved for the last twenty years, exposures to physical and psychosocial factors are still present in work environment ³. Thus, the knowledge of determinants of workplace injury and how they interact remains of interest.

The role of exposure to physical constraints in the occurrence of workplace injuries is important and its effect has been explored extensively in the literature. Thus, longitudinal studies have shown increased risk of workplace injuries for workers exposed to high physical demand ^{5,6}, heavy loads ⁷, awkward postures ⁸, vibrations ^{9,10}, loud noises ^{11,12}, cold temperatures ¹³, and excessive heat ^{10,14}.

On the other hand, there is very little literature on the relationship between psychosocial risks factors and the occurrence of workplace injuries. Studies on the subject are mostly cross-sectional ¹⁵⁻¹⁸ or focused on targeted populations ^{15, 17-20}. Prospective studies analyzing the effect of psychosocial risk factors on the occurrence of workplace injuries are scarce. Recently, a Spanish prospective cohort study with a 1-year follow-up ²¹ concluded that poor quality psychosocial work environments increased the incidence of workplace injuries, but it did not take into account information related to physical working conditions. In 2015, a prospective study of the general

working population in Norway ²² found an excess risk of workplace injuries attributable to psychosocial work factors such as job strain, emotional demand and role conflict, but without taking into account interactions with physical work factors. In 2019, a prospective cohort study investigated the risk factors for back injury in the healthcare sector in Denmark and concluded that in addition to physical burden, a poor collaboration between and support from colleagues increased the risk for back injury ²⁰. In France, only cross-sectional national surveys ^{16, 23} have analyzed in recent years the effect of psychosocial factors on workplace injuries. Moreover, overall, no prospective epidemiological study has investigated the effect of the interaction between psychosocial and physical factors on the occurrence of workplace injury. To date, there is little evidence that exposure to psychosocial factors alone or associated with one or more exposures to physical factors would increase the risk of occurrence of workplace injury.

The SIP survey (“Santé et Itinéraire Professionnel” or “Health and Career Paths”) ^{24, 25} is a two wave national survey set up by the French Ministry of Health (DRESS) and the French Ministry of Labor (DARES). The aim of this survey was to obtain better understanding of the determinants of health related to working conditions and career paths. Its advantage is that a sample of the general population was interviewed rather than a specific population (activity sector, age group, active/inactive status and geographic location).

The SIP survey was particularly appropriate for meeting the objectives of our present study: first to determine the effect of psychosocial work factors on the incidence of workplace injury; and secondly to analyze the interaction between physical factors and psychosocial factors regarding the incidence of workplace injuries.

Materials and Methods

- **Study population**

The SIP survey was a two-stage longitudinal survey (2006 and 2010). Respondents to the SIP survey were randomly selected from the French population. A first draw selected 22,632 households using data from the 1999 population census. Next, within each household, a respondent was randomly selected from all residents aged between 20 and 74 in 2006. In 2006, 13648 participants were interviewed of whom 11016 participated in 2010. A trained interviewer questioned the participants at their home using a dedicated Computer-Assisted Personal Interviewing (CAPI) software application.

The questionnaires were specifically designed to the purpose of the survey. The 2006 questionnaires explored the childhood, education, occupational history and the present personal and occupational situation of each participant. The 2010 questionnaires recorded events and changes relating to health, work and personal life during the follow-up period.

The present paper focused on the respondents who were in employment in 2006 and interviewed again in 2010. We thus excluded both the subjects who were unemployed in 2006 and those who were lost to follow-up in 2010. Finally, our study sample consisted of 6842 subjects.

- **Outcome: workplace injuries**

The workplace injuries we consider in this paper are either the workplace injuries from the year 2006 recorded in the first survey or the workplace injuries, which had occurred between 2006 and 2010 and reported in 2010.

The injuries queried were defined as serious injuries (disrupting the professional path, having caused a significant change in working conditions, having caused the end of a job, an apprenticeship or professional training, having been the cause of a handicap or having generated life disturbances). For each workplace injury, the following items were obtained:

- Injury type (at work, on the journey between home and place of work, other);
- Year;
- Sick leave for at least six months;
- Long-term consequences (partial or total disability, partial or total incapacity, handicap).

- **Risk factor definitions**

The following risk factors, present in 2006, were recorded, using *ad hoc* items ranked on a 4-point Likert scale (never, sometimes, often and permanently exposed):

○ **Physical work factors**

- Loud noise (exposure to frequent intense noise);
- Vibrations (exposure to significant forces or vibrations from tools, machines, vehicles);
- Heavy loads (carrying heavy loads during handling);
- Extreme temperatures (exposure to cold, heat, humidity or dirt);
- Awkward or uncomfortable postures (painful or tiring postures in the long run, prolonged standing, squatting, bending over, arms in the air, twisted, forced position);
- Repetitive tasks (repetitive work under time constraints or assembly line work).

In addition to these six items, a last summary question asked whether the work was physically demanding (heavy loads, strenuous postures, noise, extreme temperatures, and vibrations).

○ **Psychosocial work factors**

According to a consensus statement of French experts²⁶, the 19 items were classified into 6 sub-groups as follows:

- Labor intensity (4 items: work under pressure, too many tasks to think about, excessive workload, often more than 48 working hours in a week), working time (4 items: night work, shift work, frequent business trips, irregular and unpredictable working hours) and work-family life imbalance (1 item: difficulties reconciling work and family life);
- Emotional demand (3 items: necessity to hide or fake emotions, fear for own safety or that of others during work, tension with the public);
- Autonomy (2 items: skills not fully utilized, no choice in how a job is done);
- Social relationships at work (2 items: work not fully appreciated, poor relationships with colleagues);
- Conflict of values (2 items: necessity to undertake tasks that the person disapproves of at work, no opportunity to perform high-quality jobs);
- Job insecurity (1 item: fear of job loss).

A synthetic exposure score was defined for each sub-group (1 when at least one item of the sub-group was filled in “often” or “permanently”, and otherwise the value 0).

In addition to these factors, exposure to toxic or noxious substances (dust, smoke, microbes, and chemicals) was also recorded (1 item).

- **Other covariates**

In 2006, the following characteristics were collected: gender, age, level of education, body mass index (BMI), family structure (living with a partner or in a nuclear family, living alone, alone with an ascendant or in a single-parent family). We defined a precarious situation in the case of imbalance between incomes and household needs or a history of precarious housing.

Furthermore, information about alcohol consumption, smoking and the use of psychoactive drugs was obtained. A high alcohol consumption profile was defined when participants drank alcohol at least twice a week and had 6 drinks and more at one time at least once a month. Risky behaviors were defined as high alcohol consumption, daily smoking or at least one anxiolytic drug per week. We defined the presence of sleep problems when the participants declared they had insufficient sleep several times a week, experienced sleep disturbances several times a week, or consumed sleeping pills at least once a week.

Four variables related to the employment situation: type of contract (open-ended contract, fixed-term or temporary contract), occupation according to the International Standard Classification of Occupations ISCO, job activity (“production, maintenance and storage”, “care & services to individuals” and “office job: administration, R&D, education, business”) and the percentage of jobs of less than 5 years in the entire professional career (<5%, 5-25% and >25%). A history of injuries during work and/or daily life was also queried.

- **Statistical analysis**

Injury rates were computed in workplace injuries per 1000 person-years at work (taking into account part-time work and periods of unemployment).

The association between workplace injuries and risk factors was modelled using multiple Poisson regressions with the logarithm of the person-years at work as offset and with the occurrence of at least one workplace injury as the outcome. We considered as adjustment factors the risk factors among the other covariates for which the p-value was below 0.20.

Firstly, we fitted a model for each physical factor and each psychosocial factor adjusting for sex, age class, occupation, job activity, history of injuries or precarious situation. We fitted additional models with interaction with age classes and gender.

Secondly, we considered the multiple effects of the occupational risk factors. As the number of risk factors was too high to fit a joint model, we defined a profile for physical exposure and a profile for psychosocial exposure using hierarchical clustering with a Euclidean distance dissimilarity measure and the Ward agglomeration algorithm (5).

We thus identified 4 physical groups clustered around 6 physical factors (loud, vibrations, heavy loads, extreme temperatures, awkward or uncomfortable postures and repetitive tasks) and 3 psychosocial groups clustered around all the psychosocial factors. Finally, we fitted these two cluster variables in interaction in a Poisson regression model, adjusted for sex, age class, history of injuries or precarious situation.

All the analyses were performed with Stata version 16.0. We set the statistical significance level at 0.05.

- **Ethics Review and Approval**

The study has received the necessary regulatory approvals and has been performed in accordance with the ethical standards (National Statistics Label Committee, visa n°2006X101SA and n° 2010X054SA; National Committee for the Protection of Privacy and Civil Liberties, n°1179915 and n°2010-352).

All the subjects gave free written and informed consent to participate.

Results

- **Characteristics of the study population**

The majority of the 6842 study participants were women (52%). The average age was 43.4 years in 2006 (SD=10.4). Half of the respondents had at least a level above the secondary school certificate and 18% of the subjects had no academic qualification. One-fifth of the study population lived in a precarious situation in 2006 (Table 1).

Employees were the most numerous (30%), followed by intermediate occupations (25%), and blue-collar workers (22%). All sectors of activities were represented. Seventy percent of the participants came from the service sector, 25% from production and 5% from the primary sector (not shown). One in five reported being on a temporary contract for the last job declared in 2006.

- **Description of workplace injuries**

Between 2006 and 2010, 225 subjects reported 246 workplace injuries (70% among male). The mean age of occurrence of workplace injuries was 43.1 years (sd=10.7). Nine percent of the participants reporting workplace injury experienced several workplace injuries during the period. Fourteen percent of workplace injuries resulted in a sick leave of more than 6 months and 7% resulted in heavy sequelae (Table 2).

Sixteen percent of the participants had at least one injury (workplace injury or daily life injury) and 4% had experienced a previous workplace injury (Table 2).

- **Rates of workplace injuries**

The overall workplace injury rate was 6 per 1000 person-years. It was higher for men, subjects under 30, with lower levels of education, living alone, obese or overweight, who had experienced a precarious situation, events during childhood, and adopting risky health behaviors (Table 1, last column).

According to the NACE classification of activities, the highest rates calculated over the period concerned the sector of “agriculture, livestock, fishing” (13 per 1000 person-years), then “construction, buildings, civil engineering” (9 per 1000) and finally “trade, repair, transport, post” (7 per 1000 workers). The higher the average rate of workplace injuries (Table 1), the higher the percentage of job held for less than 5 years in the participants’ entire professional career. Finally, the average annual rate of workplace injuries increased with the number of previous workplace injuries reported prior to inclusion (for one antecedent: 5.5, for 2 16.1 and for 3 and over 28.7 per 1000). The same

observation could be made for history of work and/or daily-life injuries (for 1 5.2, for 2 8.7 and for 3 17.8 per 1000) (data not shown).

- **Associations between exposure to physical risk factors and workplace injury**

The risk of workplace injuries was in significant excess for all physical risk factors except repetitive work (Table 3). This risk was highest for workers reporting extreme temperature (IRR=2.45 [1.79-3.37]) and when exposed to two or more physical factors (IRR=2.84 [1.90-4.23]). Moreover, exposure to toxic or noxious substances (IRR=1.36 [1.01-1.82]) and physically demanding jobs (IRR=1.58 [1.19-2.09]) was associated with significantly increased IRRs.

None of these IRRs differed significantly between males and females. However, we observed a significant increase in women exposed to repetitive work (IRR=1.83 [1.09-3.09]) which was non significant among males (Table 3). No significant difference was observed according to age group (Supplemental Digital Content 1). Nevertheless, when considering the number of physical risk factors, the IRRs differed significantly with age group, due to higher IRRs in the youngest age group (≤ 30). On the contrary, the IRRs with toxic or noxious exposures differed according to age, with the oldest age group having the highest IRR (2.29 [1.35-3.88]) (Supplemental Digital Content 1).

The results were qualitatively similar in models without adjustment (Supplemental Digital Content 2).

- **Associations between exposure to psychosocial factors and workplace injury**

Psychosocial factors associated with the incidence of workplace injuries were mostly related to emotional demand (IRR=1.57 [1.19-2.06]), conflict of values (IRR=1.35 [1.00-1.84]), labor intensity with excessive workload (IRR=1.38 [1.03-1.85]) and working more than 48 hours per week (IRR=1.56 [1.09-2.25]), work-family life imbalance (1.60 [1.09-2.33]) and working time (IRR=1.43 [1.09-1.88]) (Table 4). Within the latter, participants reporting irregular and unpredictable working hours had a higher risk of workplace injuries (IRR=1.63 [1.18-2.25]).

No significant difference was observed according to gender except for shift-work (IRR=0.75 [0.48-1.17] in males vs. IRR=1.53 [0.85-2.76] in females). Concerning social relationships at work, we observed a significant increase for women reporting a lack of reward (IRR=1.77 [1.09-2.88]) (Table 4).

No significant difference was observed according to age group, but we observed higher IRRs in the youngest age group (≤ 30) especially when they reported high emotional demand (IRR=2.39 [1.25-4.59]), lack of autonomy

(IRR=2.09 [1.11-3.94]), lack of reward (IRR=1.89 [1.01-3.54]) or the necessity to undertake tasks that the person disapproves of at work (IRR=2.34 [0.98-5.59]) (Supplemental Digital Content 3).

The results of the Poisson regression models without adjustments are presented in Supplemental Digital Content 4.

- **Joint effect between physical and psychosocial work factors**

The cluster analysis of the physical factors led to the identification of four rather balanced groups that we characterized as non-exposed; low exposure but repetitive tasks; moderate exposure to heavy loads and awkward postures; and multiple exposure (Supplemental Digital Content 5). The cluster analysis of the psychosocial factors led to the identification of three groups: low psychosocial exposure; mostly high exposure to fear for safety and specific schedules; mostly high exposure to job and emotional demand (Supplemental Digital Content 5).

We observed a strong dose-response relationship between workplace injuries occurrence and physical exposure, with a model-based incidence rate of 9.44 [7.58-11.30] workplace injuries per 1000 workers for the multiple physical exposure group (Figure 1a). Workers with high psychosocial exposure had a higher model-based incidence rate of workplace injuries than workers with low psychosocial exposure (respectively 6.68 [5.60-7.75] workplace injuries per 1000 vs 4.74 [3.61-5.86] workplace injuries per 1000, $p=0.019$) (Figure 1b).

When fitting the two series of groups simultaneously (Figure 1c), there was still a strong dose-response between workplace injury occurrence and physical exposure. However the difference between the 2 psychosocial exposure groups was no longer significant ($p=0.158$, data not shown) (Figure 1c).

Finally, the interaction between physical and psychosocial exposures was non-significant ($p=0.690$, data not shown). However, Figure 2 shows that the difference in model-based workplace injury incidence rate between high and low psychosocial exposures seemed to increase with increasing physical exposure.

Discussion

Our epidemiological study is one of the first to deal with the joint effect between physical and psychosocial risk factors on the occurrence of workplace injury. Our results confirmed the main role of physical factors as determinants of workplace injury: the higher the reported exposure to physical risk factors, the higher the risk of workplace injury. Psychosocial factors related to emotional demand, labor intensity, working time, work-family imbalance and conflict of values were associated with the incidence of workplace injury. However, physical factors and psychosocial factors were partially confounded, as psychosocial factors no longer had a significant effect when taking into account the effect of physical factors. Nevertheless, the greatest risk of workplace injury was for workers exposed simultaneously to multiple physical and psychosocial factors. Finally, there was no significant effect of psychosocial exposure on workplace injury occurrence among those not exposed to physical factors.

Apart from autonomy and social relationships at work, all the other psychosocial factors were associated with the occurrence of workplace injuries. According to Halbesleben²⁷, prolonged exposure to psychosocial work stressors may lead to emotional exhaustion that deteriorates the worker's capability to ensure safe behavior, encourages them to circumvent the rules and may increase the risk of workplace injuries. The association of a low autonomy with workplace injury occurrence is controversial in the literature. Some studies found significant over-risk of workplace injuries^{10,28}, while others did not¹⁹. The perception of job control may differ according to workers' characteristics, resulting in potential differential effects in terms of workplace injuries. For example, we previously showed that the perception of job control increased with age until age 30²⁹. In our study, only workers under 30 who declared that they did not fully use their skills had a higher risk of workplace injury.

We observed a higher risk of workplace injuries for workers declaring being exposed to an excessive workload. The association between high job demand or excessive working time and workplace injuries is well known in the literature^{15,19}. Similarly, workers reporting difficulties of reconciling work and family life had a higher risk of workplace injuries³⁰. This can be explained by the fact that the more time you spend at work, the more you are exposed to a potential risk of workplace injury. In addition, having long working days or mental overload due to work-family imbalance can lead to more fatigue, decreased alertness and therefore greater vulnerability to workplace injury.

Our results show a higher risk of workplace injuries when workers declared organizational time constraints. In particular, in line with the observations of previous studies²³, having irregular and non-predictable working hours increases the risk of workplace injury. As Niedhammer et al.³¹ showed, shift work was found to be a risk factor for workplace injuries for women only. Some studies found an increased risk of workplace injuries after a week

that included evening or night work compared to those who worked only during the day^{32, 33}. Horwitz et al. described a greater risk of workplace injuries among workers working in the evenings than at night³⁴. According to Wagstaff, shift work including nights comprised a substantial increased risk of workplace injury, whereas fixed night work may contribute some protection against workplace injury occurrence due to resynchronization³⁵. In addition, night workers perform work tasks differently from day workers (workload, supervision, isolation)^{36, 37}. In contrast, our results showed no effect of night or shift work on workplace injury occurrence. This may be due to a lack of standard definition of this factor.

We found that high emotional demand led to excess risk of workplace injuries. In particular, this risk appeared to be highest for workers under the age of 30, for males declaring a fear for their own safety or for the safety of colleagues and females who work in an atmosphere of tension with the public, or who have to hide or fake emotions. Other studies also reported a high risk of workplace injuries in relation to emotional demand^{22, 38}.

The risk of workplace injuries was statistically higher for workers reporting conflicts of values (necessity to carry out tasks that the person disapproves of at work or no opportunity to perform high-quality jobs), especially for men. To our knowledge, the present study is the first to report an excess risk of workplace injuries in relation with conflicts of values. However, these findings must be confirmed using a more complete and validated tool for measuring exposure to this multidimensional concept.

Surprisingly, our results did not show a significant association between job insecurity and workplace injury occurrence. This finding is similar to that of previous studies^{19, 23} and does not conform with that of Probst et al. who reported that employees reporting high perceptions of job insecurity exhibit decreased safety motivation and compliance, and therefore increased levels of workplace injury³⁹.

As Julià et al.²¹ pointed out, taking into account the multi-exposure of physical and psychosocial factors to explain workplace injury occurrence is rare. Although the hierarchical classification allowed clearly distinguishing four categories of exposure to physical risk factors ranging from a non-exposure situation to a multi-exposure situation corresponding to increasing risks, it did not identify combinations of specific psychosocial factors with a high risk of workplace injuries. In our study, we were only able to clearly identify an overall exposed group and a low exposed group. The highest psychosocial exposure group corresponded to multiple psychosocial exposures and in particular high job demand, high emotional demand and lack of reward (Supplemental Digital Content 5). The lowest corresponded to low exposure to all psychosocial dimensions (Supplemental Digital Content 5). Interestingly, no group could be identified without any psychosocial exposure. Thus, knowledge about the

combination of psychosocial factors with the most deleterious effects is lacking. Studies focusing on the effect of potential interaction between different psychosocial factors on workplace injury occurrence are scarce. When physical factors were not taken into account in the models, the risk of workplace injuries was higher for workers more frequently exposed to psychosocial factors compared to the lowest psychosocial factors group. However, physical factors and psychosocial factors were partially confounded, as psychosocial factors no longer had a significant effect when taking into account the effect of physical factors. This is not due to total overlap of physical and psychosocial factors. Our results suggest that psychosocial exposure may potentiate the effect of multiple physical factors on the occurrence of workplace injuries. We observed larger trend, albeit non-significant, according to physical factor when workers were exposed jointly to multiple physical and psychosocial factors.

Our results confirmed the main role of physical risk factors as determinants of the occurrence of workplace injuries. Indeed, the risk of workplace injuries was in excess for most of the physical risk factors. Our results are in line with those of previous studies that showed an excess risk of workplace injuries when workers were exposed to handling heavy loads ⁷, awkward or uncomfortable postures ⁸, loud noises ^{11, 12}, vibrations ^{9, 10} or extreme temperatures ^{10, 13, 14}. In accordance with the literature on physical workload ^{5, 6, 22}, in our study, workers who explicitly reported physically demanding work were at greater risk of workplace injury. This was especially true when workers were exposed to two or more physical factors simultaneously. The hierarchical classification confirmed the above results since a strong dose-response relationship between workplace injury occurrence and physical exposure was found. Finally, in line with the findings of a previous literature review¹², workers exposed to toxic or noxious substances were found to have a high risk of workplace injuries.

Our results did not show any statistically significant interaction with gender and physical risk factors. Nevertheless, we found a significant excess risk of workplace injuries only for women exposed to repetitive work. As described in previous French studies ^{40, 41}, the risk of workplace injuries in the case of repetitive work was not significant. In our study, although there was no significant interaction, some trends were significant only among women with respect to the effect of exposures to noise, vibration, extreme temperatures, repetitive work and toxic or noxious substances on the occurrence of workplace injury. However, for men the risk of workplace injuries appeared to be higher than for women in the case of exposure to handling heavy loads and awkward or uncomfortable postures. These discrepancies according to gender can be explained by the fact that the type of tasks is generally different between females and males.

Concerning age, the results did not show any statistically significant interaction regarding the six items of physical risk factors. However, our results showed a trend for the over 50s to be more vulnerable to workplace injuries when exposed to noise, vibration, handlings heavy loads, or extreme temperatures. Moreover, these senior workers have a higher risk of workplace injuries when exposed to toxic or harmful substances, as indicated by the significant interaction of this variable with the oldest age group having the highest IRR. When considering the number of physical risk factors simultaneously, the IRRs differed significantly with age group, due to higher IRRs in the youngest age group (≤ 30). These results are in line with the statements of a U.S. and Canadian series of symposia⁴² where it was explained that young workers are more vulnerable than older workers because of a lack of experience and because of their attitude towards occupational safety and health.

Strengths and limits

One of the strengths of study was that it was based on a large prospective randomly selected sample of the French working population. The face-to-face interviews were carried out by trained interviewers using a dedicated Computer-Assisted Personal Interviewing software application, thereby reducing the amount of missing data.

The data collected related only to self-reported injuries that had resulted in serious consequences for work or employment. The self-questionnaire did not provide a fine characterization of the severity of the reported workplace injuries. Similarly, the data did not accurately characterize the nature or the circumstances of workplace injuries, whereas the problem may differ depending on whether physical injuries or psychological injuries were involved. The workplace injuries considered did not represent all workplace injuries, thus there may have been a reporting bias. Obtaining data from registers with systematic collection would have made it possible to have more complete and certainly more accurate information. Likewise, the assessment of physical and psychosocial risk factors were not based on standardized questionnaires, possibly resulting in a less precise characterization.

With every epidemiology studies, caution is required when concluding in terms of causality. However, the prospective design of our work, using physical and psychosocial exposures of 2006 to predict the later occurrence of workplace injuries, prevents memory and information bias.

Clusters of exposure to physical risk factors and psychosocial factors were defined independently of outcomes. The two hierarchical classifications summarized the large number of available variables and thus allowed us to analyze the interaction between these two types of exposure. It would have been interesting to perform a gender classification, given the well-known differences in the perception of psychosocial risks for men and women.

However, the sample size in our study, although substantial, remained too limited to perform classification by gender.

Only subjects in employment in 2006 who were re-interviewed in 2010 were retained in our study, resulting in exclusion of subjects who did not respond in 2010. However, the selection bias seems limited. Although subjects lost of follow-up had a typical profile of injured workers (men, young, low education, and precarious contracts) (data not shown), there was no difference with the study participants in terms of occupation, history of workplace injuries or accidents of any type.

The precise collection of the professional careers of the workers throughout the follow-up period was a strong point. Indeed, the working time actually worked was taken into account in the analyses, including a weighting based on part-time and reported unworked periods. This improved the accuracy of the estimate of the probability of a workplace injury.

Another advantage of the study was to have collected information about the history of workplace injuries and precariousness. These data, rarely taken into account in the literature, were incorporated in the analyses and allowed good consideration of the factors that are known to have an effect on the occurrence of workplace injury.

Conclusion

High psychosocial exposure had a deleterious effect on workplace injuries incidence, which was no longer significant when adjusting for physical factors. The risk of workplace injuries was highest among workers with high physical exposures regardless of the psychosocial exposures.

Although working conditions are evolving, exposures to physical and psychosocial factors are still present in workplaces and the identification of factors associated with the occurrence of workplace injury remains of interest. Future research should focus on identification of the most deleterious risk combinations of multi-exposure to physical and psychosocial risk factors in the occurrence of workplace injury. All this new knowledge should make it easier to promote and implement appropriate prevention programs in companies.

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Table 1 Characteristics of participants at the time of inclusion in 2006 and annual average rates of workplace injuries (WI)

	(N=6842)		WI	annual average rate of Wi ^a	
	n	%			
Gender	male	3277	47.9	157	8.6
	female	3565	52.1	68	3.5
Age (years)	≤30	895	13.1	39	7.8
	30-50	3723	54.4	127	6.0
	≥50	2224	32.5	59	5.2
Level of education	no diploma/lower education	1205	17.6	50	8.0
	CAP/BEP certificates	2278	33.3	97	7.7
	baccalaureate	1180	17.2	41	6.2
	higher education	2179	31.8	37	3.0
Family structure	alone/one-parent family/with ascendant	1649	24.1	57	6.3
	with a partner/nuclear family	5193	75.9	168	5.9
Precarity: experience of a precarious situation^b	yes	1506	22.0	78	9.6
	no	5336	78.0	147	5.0
Overweight or obesity^c	yes	2741	40.1	103	6.9
	no	4032	58.9	121	5.4
	missing	69	1.0		
Health behaviour: number of risky behaviour^d	0	3863	56.5	112	5.3
	1	2192	32.0	72	6.0
	2+	787	11.5	41	9.4
Sleep problem^e	no	4591	67.1	145	5.7
	yes	2251	32.9	80	6.5
Occupation	farmers, farm workers, growers	206	3.0	16	14.1
	craftsmen, merchants, business manager	358	5.2	8	4.1
	executives and higher intellectual professions	1012	14.8	11	2.0
	intermediate professions	1722	25.2	41	4.3
	employees	2049	30.0	50	4.5
	blue collar workers	1487	21.7	99	12.0
	missing	8	0.1		
Job activity	office job (administration, R&D, education, business)	3085	45.1	54	3.2
	care & services to individuals	1493	21.8	43	5.3
	production, maintenance and storage	2233	32.6	127	10.3
	missing	31	0.5		
Work contract	open-ended contract	5649	82.6	186	5.9
	fixed-term or temporary contract	1193	17.4	39	6.0
Percentage of job of less than 5 years in the entire professional career	<5%	2526	36.9	71	5.1
	5-25%	2381	34.8	80	6.2
	>25%	1935	28.3	74	6.9

^aAnnual average rate of workplace injuries per 1000: (number of workplace injuries / person-years*1000) weighted by part-time work

^bPrecarious housing or imbalance between incomes and household needs

^cBody mass index (BMI) >25

^dHigh alcohol consumption / daily smoking / taking anxiolytics at least once a week

^esleep deprivation / sleep disorders / taking sleeping pills

Table 2 Description of workplace injuries (WI) occurred between 2006 and 2010

	(N=6842)		%
		n	
At least one WI during the period	no	6617	96.7
	yes	225	3.3
Number of WI occurred during the period	1	205	91.1
	2	19	8.5
	3	1	0.4
Severity of the injury (sick leave longer than 6 month LSL or/and heavy sequelae HS^a)^b	no LSL - no HS	179	79.6
	with LSL but no HS	31	13.8
	with HS	15	6.6
Sustained previous injury(ies)^c	0	5770	84.3
	1	903	13.2
	2+	169	2.5
Sustained previous workplace injury(ies)	0	6557	95.8
	1	250	3.7
	2+	35	0.5
Average age of first occurrence of WI during the period	mean (sd)	43.1	(10.7)

^a the most serious injury is considered when several injuries occurred in the period

^b heavy sequelae means total disability, total incapacity or handicap

^cduring work or during daily life (sport, road...)

Table 3 Associations between exposures to physical risk factors considered independently at baseline and occurrence of workplace injuries (WI) during the period 2006-2010 adjusted for covariates^a

		(N=6842)		Total			Male		Female		p ^c
		n (%)	WI	annual average rate of WI ^b per 1000	IRR	IC 95%	(N=3277) WI = 157	IC 95%	(N=3565) WI = 68	IC 95%	
Physical risk factors ^d											
loud noise	yes	1140 (16.9)	66	10.5	1.37*	1.01 - 1.85	1.25	0.88 - 1.77	1.81*	1.02 - 3.20	0.268
	no	5625 (83.1)	155	5.0	ref		ref		ref		
intensive vibrations or efforts using tools, machinery or vehicles	yes	619 (9.2)	60	17.5	2.03***	1.46 - 2.82	1.93***	1.36 - 2.73	2.87**	1.29 - 6.38	0.364
	no	6146 (90.8)	161	4.8	ref		ref		ref		
handling heavy loads	yes	1384 (20.5)	96	12.7	2.02***	1.52 - 2.69	2.34***	1.68 - 3.27	1.36	0.78 - 2.36	0.091
	no	5381 (79.5)	125	4.2	ref		ref		ref		
extreme temperatures	yes	1978 (29.2)	138	12.6	2.45***	1.79 - 3.37	2.41***	1.64 - 3.52	2.55***	1.54 - 4.22	0.856
	no	4787 (70.8)	83	3.2	ref		ref		ref		
awkward or uncomfortable postures	yes	2574 (38.0)	127	9.0	1.62***	1.23 - 2.15	1.76***	1.26 - 2.45	1.35	0.82 - 2.22	0.380
	no	4191 (62.0)	94	4.1	ref		ref		ref		
repetitive tasks	yes	1188 (17.6)	60	9.2	1.24	0.91 - 1.69	1.05	0.72 - 1.52	1.83*	1.09 - 3.09	0.083
	no	5577 (82.4)	161	5.3	ref		ref		ref		
Number of physical risk factors (among the 6 first items)	0	3012 (44.5)	38	2.3	ref		ref		ref		0.381
	1	1323 (19.6)	39	5.4	1.78**	1.12 - 2.82	2.14**	1.16 - 3.94	1.41	0.70 - 2.87	
	2+	2430 (35.9)	144	10.8	2.84***	1.90 - 4.23	3.41***	2.02 - 5.76	2.22**	1.24 - 3.97	
Toxic or noxious substances	yes	1302 (19.2)	75	10.4	1.36*	1.01 - 1.82	1.25	0.89 - 1.74	1.76*	1.01 - 3.09	0.289
	no	5463 (80.8)	146	4.9	ref		ref		ref		
Physically demanding work (heavy loads, strenuous postures, noise, extreme temperature, vibration)	yes	2411 (35.6)	121	9.1	1.58***	1.19 - 2.09	1.72***	1.23 - 2.40	1.30	0.79 - 2.14	0.353
	no	4354 (64.4)	100	4.2	ref		ref		ref		

^aPoisson regression models with adjustment on covariates: gender, age class, occupation, job activity, history of injuries, history of precarious situation

^bAnnual average rate of workplace injuries per 1000: (number of workplace injuries / person-years*1000) weighted by part-time work

^cWald test for interaction

^dyes Always/Often ; no Sometimes/Never

Missing values <1,3%

Table 4 Associations between exposures to psychosocial risk factors considered independently at baseline and occurrence of workplace injuries (WI) during the period 2006-2010 adjusted for covariates^a

		(N=6842) WI = 225 n (%)	Population annual average rate of WI ^b				Male (N=3277) WI = 157		Female (N=3565) WI = 68		p ^c
			WI	per 1000	IRR	IC 95%	IRR	IC 95%	IRR	IC 95%	
dimension 1: labour intensity and working time											
Labour intensity (at least one of the following items)											
	yes	3946 (58.3)	137	6.3	1.24	0.93 - 1.64	1.39	0.99 - 1.96	0.97	0.59 - 1.58	0.232
	no	2819 (41.7)	84	5.5	ref		ref		ref		
	Work under pressure										
	yes	1964 (29)	57	5.3	0.96	0.71 - 1.30	0.90	0.63 - 1.30	1.11	0.64 - 1.95	0.534
	no	4801 (71)	164	6.2	ref		ref		ref		
	Too many tasks to think about										
	yes	3012 (44.5)	84	5.0	0.89	0.67 - 1.18	0.88	0.63 - 1.22	0.94	0.56 - 1.56	0.824
	no	3753 (55.5)	137	6.7	ref		ref		ref		
	Excessive workload										
	yes	1524 (22.5)	63	7.5	1.38*	1.03 - 1.85	1.36	0.96 - 1.92	1.44	0.84 - 2.49	0.853
	no	5241 (77.5)	158	5.5	ref		ref		ref		
	Working more than 48 hours per week										
	yes	1130 (16.7)	52	8.3	1.56**	1.09 - 2.25	1.79**	1.21 - 2.64	0.85	0.34 - 2.13	0.138
	no	5635 (83.3)	169	5.5	ref		ref		ref		
Working time (at least one of the following items)											
	yes	1975 (29.0)	98	8.9	1.43**	1.09 - 1.88	1.35	0.98 - 1.85	1.68*	1.01 - 2.79	0.469
	no	4790 (71.0)	123	4.7	ref		ref		ref		
	Night work										
	yes	525 (7.8)	25	8.4	0.98	0.64 - 1.50	0.92	0.57 - 1.48	1.28	0.51 - 3.21	0.533
	no	6240 (92.2)	196	5.7	ref		ref		ref		
	Shift work										
	yes	922 (13.6)	39	7.6	0.94	0.66 - 1.35	0.75	0.48 - 1.17	1.53	0.85 - 2.76	0.050*
	no	5843 (86.4)	182	5.7	ref		ref		ref		
	Frequent business trips										
	yes	261 (3.9)	15	10.4	1.68	0.99 - 2.87	1.75*	1.00 - 3.05	1.13	0.16 - 8.16	0.676
	no	6504 (96.1)	206	5.8	ref		ref		ref		
	Irregular and non-predictable working hours										
	yes	988 (14.6)	52	9.5	1.63**	1.18 - 2.25	1.78**	1.23 - 2.55	1.24	0.64 - 2.45	0.361
	no	5777 (85.4)	169	5.3	ref		ref		ref		
Work-family life imbalance											
	Difficulties reconciling work and family life										
	yes	685 (10.1)	33	8.6	1.60**	1.09 - 2.33	1.46	0.92 - 2.33	1.92*	1.00 - 3.68	0.508
	no	6080 (89.9)	188	5.6	ref		ref		ref		
dimension 2: emotional demand											
emotional demand (at least one of the following items)											
	yes	3204 (47.4)	115	6.5	1.57***	1.19 - 2.06	1.56**	1.13 - 2.16	1.57	0.95 - 2.60	0.986
	no	3561 (52.6)	106	5.4	ref		ref		ref		
	Necessity to hide or fake emotions										
	yes	2813 (41.6)	86	5.6	1.31	0.98 - 1.75	1.14	0.80 - 1.62	1.75*	1.06 - 2.88	0.164
	no	3952 (58.4)	135	6.2	ref		ref		ref		
	Fear for own safety or for safety of others during work										
	yes	529 (7.8)	44	15.0	2.06***	1.47 - 2.88	2.15***	1.47 - 3.13	1.74	0.83 - 3.67	0.622
	no	6236 (92.2)	177	5.2	ref		ref		ref		
	Tensions with the public										
	yes	728 (10.8)	29	7.2	1.63*	1.09 - 2.42	1.40	0.83 - 2.37	2.04*	1.11 - 3.76	0.355
	no	6037 (89.2)	192	5.8	ref		ref		ref		

dimension 3: autonomy											
autonomy (at least one of the following items)											
	yes	1848 (27.3)	77	7.6	1.23	0.93 - 1.63	1.14	0.81 - 1.60	1.45	0.88 - 2.39	0.439
	no	4917 (72.7)	144	5.3	ref		ref		ref		
	Skills not fully utilized										
	yes	861 (12.7)	36	7.7	1.20	0.83 - 1.72	1.21	0.78 - 1.86	1.18	0.61 - 2.25	0.946
	no	5904 (87.3)	185	5.7	ref		ref		ref		
	No choice in how a job is done										
	yes	1343 (19.9)	56	7.6	1.16	0.85 - 1.58	0.99	0.68 - 1.45	1.64	0.97 - 2.78	0.128
	no	5422 (80.1)	165	5.5	ref		ref		ref		
dimension 4: social relationships at work											
social relationships at work (at least one of the following items)											
	yes	2352 (34.8)	96	7.4	1.26	0.96 - 1.65	1.08	0.78 - 1.49	1.80*	1.11 - 2.93	0.086
	no	4413 (65.2)	125	5.2	ref		ref		ref		
	Lack of reward										
	yes	2198 (32.5)	89	7.3	1.24	0.95 - 1.63	1.06	0.77 - 1.48	1.77*	1.09 - 2.88	0.090
	no	4567 (67.5)	132	5.3	ref		ref		ref		
	Poor relationships with colleagues										
	yes	427 (6.3)	23	9.9	1.46	0.95 - 2.26	1.35	0.79 - 2.30	1.75	0.83 - 3.67	0.576
	no	6338 (93.7)	198	5.7	ref		ref		ref		
dimension 5: conflict of values											
conflict of values (at least one of the following items)											
	yes	1270 (18.8)	54	7.7	1.35*	1.00 - 1.84	1.43*	1.00 - 2.05	1.17	0.66 - 2.08	0.568
	no	5495 (81.2)	167	5.5	ref		ref		ref		
	Necessity to undertake tasks that the person disapproves of at work										
	yes	421 (6.2)	20	8.6	1.30	0.82 - 2.07	1.41	0.84 - 2.37	1.01	0.37 - 2.78	0.567
	no	6344 (93.8)	201	5.8	ref		ref		ref		
	No opportunity to perform high-quality jobs										
	yes	1023 (15.1)	40	7.1	1.26	0.89 - 1.77	1.28	0.84 - 1.94	1.21	0.66 - 2.22	0.884
	no	5742 (84.9)	181	5.7	ref		ref		ref		
dimension 6: job insecurity											
	Fear of job loss										
	yes	543 (8.0)	23	9.7	1.11	0.72 - 1.71	0.99	0.58 - 1.68	1.44	0.68 - 3.03	0.417
	no	6222 (92.0)	198	7.9	ref		ref		ref		

^aPoisson regression models with adjustment on covariates: gender, age class, occupation, job activity, history of injuries, history of precarious situation

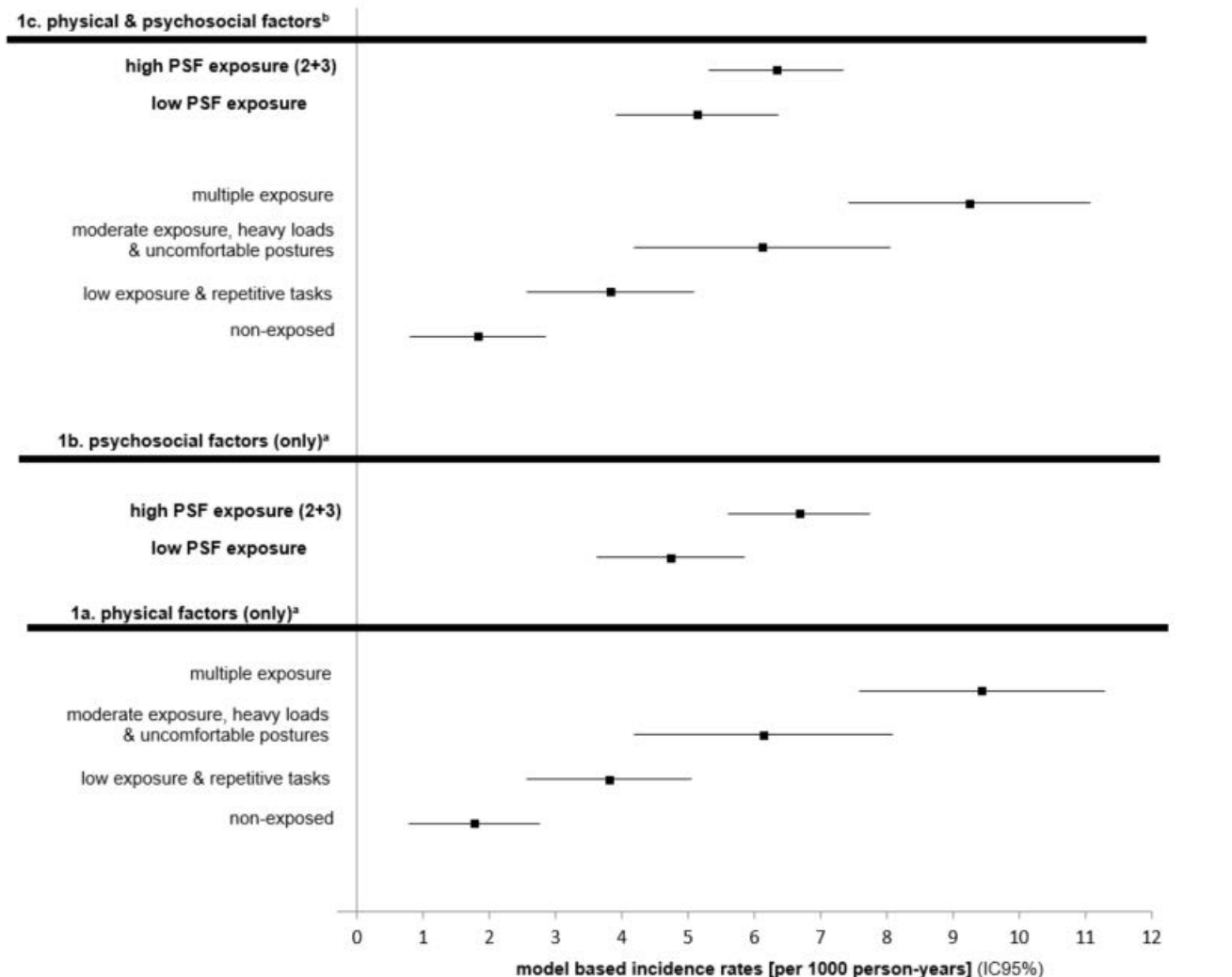
^bAnnual average rate of workplace injuries per 1000: (number of workplace injuries / person-years*1000) weighted by part-time work

^cWald test for interaction

^dyes Always/Often ; no Sometimes/Never

Missing values <1,3%

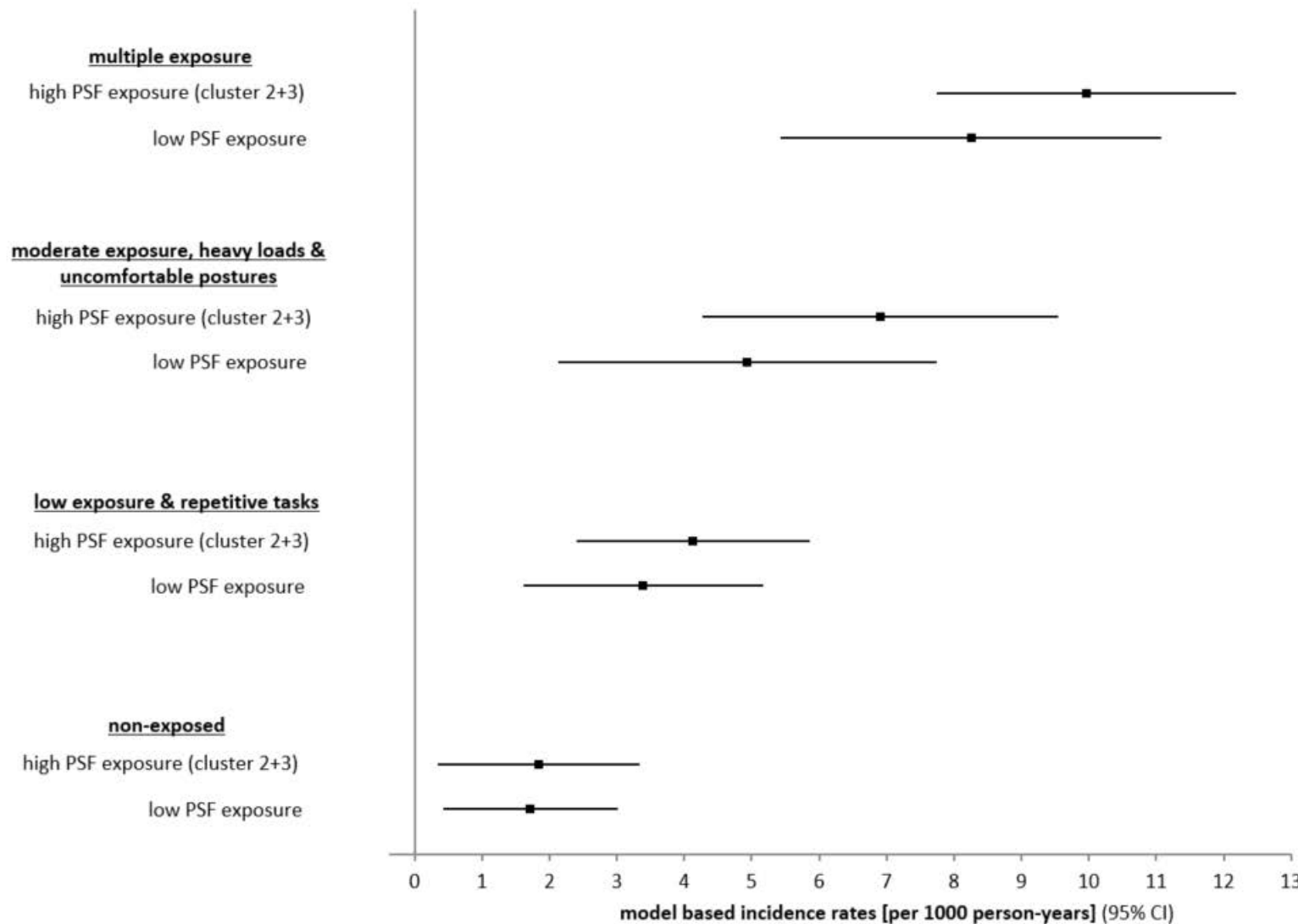
Figure 1 Associations between exposure to physical and psychosocial factors (PSF) and occurrence of workplace injuries during the period 2006-2010



^a Independent poisson regression models with adjustment on covariates : gender, age class, occupation, job activity, history of injuries, history of precarious situation
 high PSF exposure = cluster2 (fear for safety & specific schedules) + cluster3 (high job & emotional demand)

^b Joint poisson regression model with adjustment on covariates : gender, age class, occupation, job activity, history of injuries, history of precarious situation

Figure 2 Associations between joint exposure to physical and psychosocial factors (PSF) and occurrence of workplace injuries during the period 2006-2010.^a



^a Joint poisson regression model with adjustment on covariates : gender, age class, occupation, job activity, history of injuries, history of precarious situation
high PSF exposure = cluster2 (fear for safety & specific schedules) + cluster3 (high job & emotional demand)