

AN ECOLOGICAL STUDY ON THE ASSOCIATION BETWEEN CHARACTERISTICS OF HOSPITAL UNITS AND THE RISK OF OCCUPATIONAL INJURIES AND ADVERSE EVENTS ON THE EXAMPLE OF AN ITALIAN TEACHING HOSPITAL

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Abstract

Objectives: We explored the association of workplace characteristics with occupational injuries and adverse events in an Italian teaching hospital. **Material and Methods:** This ecological study was conducted using data routinely collected in the University Hospital of Udine, Northeastern Italy. Poisson regression models were used to investigate, at the hospital unit level, the association between 5 outcomes, including: occupational injuries, patient falls, medication errors, other adverse events and near-misses, and various characteristics of the units. **Results:** The proportion of female workers in a unit, the average number of sick-leave days and of overtime hours, the number of medical examinations requested by employees, and being a surgical unit were significantly associated with some of the outcomes. **Conclusions:** Despite ecological nature of the study, which does not allow for inferences to be drawn at the individual level, the results of our study provide useful clues to support strategies and interventions directed towards healthier work environments and better patient care in hospitals.

Key words:

Teaching hospital, Occupational injuries, Hospital incident reporting, Ecological study, Accidental falls, Medication errors

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INTRODUCTION

Workplace characteristics are known to influence the level of stress and the health and safety of workers, and in turn, work performance [1]. Work-related stress resulting in poorer productivity, absenteeism, and worker turnover has financial implications for organizations, and ultimately for the society [1]. Despite managers being aware of these issues, dealing with work-related stress is perceived as a difficult task [1]. Even assessment and quantification of the level of work-related stress is challenging. Routinely collected data, such as work days lost due to the sickness, have been often used to describe the extent of the problem [2]. However, these data may be imprecise and not necessarily good proxies for work-related stress. On the other hand, in the case of self-reported measures of stress, which seem to be more representative of the phenomenon, a question of their validity arises [2].

In a hospital setting, other workplace factors, which may or may not be associated with work-related stress, have been shown to affect the risk of adverse outcomes. For instance, in 6 Scottish acute hospitals staffing and management support have turned to be predictors of both occupational and patient injuries [3]. Organizational climate and staffing have been also associated with needlestick injuries among the US nurses [4], and with adverse events in psychiatric care in the US hospitals [5], whereas workplace environment, organizational characteristics, and ward specialty have been associated with needlestick and sharp injuries among South Korean nurses [6].

The objective of this study was to investigate whether workplace characteristics, which can be assessed using inexpensive and readily available routinely collected data, are associated with an increased risk of occupational injuries and adverse events in an Italian teaching hospital. Identification of such characteristics, if successful, could support strategies and interventions directed towards healthier work environments and better patient care.

MATERIAL AND METHODS

This was an ecological study and it was conducted at the University Hospital of Udine, Northeastern Italy, a tertiary referral center employing approximately 3800 people. For each hospital unit, data on the outcomes of interest that occurred in 2012 and 2013 were provided by the Clinical Risk Unit. The data included information on:

- the number of occupational injuries (including commuting accidents) and incidents involving biological hazards reported by the employees (outcome 1),
- the number of patient falls (outcome 2),
- the number of medication errors (outcome 3),
- the number of other adverse events or near-misses reported by the people working in the unit where the event occurred through the hospital incident reporting system (outcome 4),
- the number of other adverse events or near-misses reported by the people working in other units through the hospital incident reporting system (outcome 5).

The incident reporting system was implemented in the University Hospital of Udine in 2008. Hospital workers who are involved in or aware of adverse events, patient falls or medication errors, either in their own unit or in other units, are encouraged to spontaneously report them through *ad hoc* forms that must be returned to the Clinical Risk Unit for an in-depth evaluation, follow-up and preventive actions [7]. To encourage the employees to report any errors or near-misses that they notice in their own or in other hospital wards, the reporting system does not collect information on the persons responsible for the reported errors/near-misses, and thus, prevents individual-level analyses of adverse events.

Information on hospital unit characteristics potentially associated with the outcomes of interest were provided by the Occupational Health Office, which abstracted data on the number of medical visits requested directly by the employees earlier than the scheduled date for a periodical worker health examination, and by the Human

Resources and Administration Office, which abstracted data concerning the number of employees, stratified by sex; the overall number of sick-leave days; the overall number of overtime hours; the number of newly hired workers and the number of those who gave up work in each unit in the years 2012 and 2013. Information on paid vacation days was also provided, but there was too little variability in this item. In fact, all the hospital workers are requested to complete all the paid vacation days allowed for a given year within that year, otherwise there is a reduction in the target achievement bonus for the whole unit in which they are employed.

Statistical analysis

For each outcome variable measured at the hospital unit level, we calculated a mean, standard deviation, quartiles, minimum and maximum values. We calculated the Pearson's correlation coefficients to assess whether the occurrence of each outcome is associated with the other outcomes. $P < 0.05$ was considered as statistically significant. For the whole population of hospital units, clustered within the departments, we built a multilevel Poisson regression model to assess the association of the number of injuries and incidents involving biological hazards in the unit (dependent variable) with the following explanatory variables: number of employees, proportion of female workers, average annual number of sick-leave days, average annual number of overtime hours, average annual number of visit requests per employee, and the ratio of new employees and workers who gave up work (> 1 : increase in the staff size; 1 : no change in the staff size despite new employees and work terminations; < 1 : decrease in the staff size; or no personnel changes).

The logarithm of the number of employees in a unit was used as an offset variable in the Poisson regression. An exchangeable working correlation structure was specified in the model. Three dummy variables were also included in the model as explanatory variables to adjust

for the potential confounding effect of the type of a hospital unit (administrative, services, medical, or surgical unit) on the association between the outcome and the hospital unit characteristics.

To account for the fact that adverse events involving patients could only occur in some hospital units and not in others, we built 5 (1 for each outcome) multilevel Poisson regression models restricted to the units the activities of which actually involve patients (thus, excluding all administrative units and services not open to patients), plus an additional model having the sum of all 5 outcomes as a dependent variable (outcome 6).

Relative risk (RR) associated with each explanatory variable, adjusted for the potential confounding effect of all the other variables, was obtained by exponentiating the Poisson regression coefficients. Precision of the estimates was expressed through the 95% confidence intervals (95% CI).

All the statistical analyses were performed with SAS version 9.2 (SAS Institute Inc., Cary, NC, USA).

Ethics

An ethical approval was obtained from the Ethics Committee of Udine, Italy.

RESULTS

In 2012 and 2013, 3815 and 3820 workers, respectively were employed in the University Hospital of Udine. Overall, in 2012 they totalled 41 205 sick-leave days, 34 109.63 overtime hours, and 53 medical visit requests; and in 2013 – 43 363 sick-leave days, 21 137.22 overtime hours, and 70 medical visit requests. The total number of events and the distribution of each are reported in Table 1.

We found that the frequency of each outcome in a unit increased proportionally to the increasing number of people employed in that unit. In fact, the number of employees was significantly correlated with injuries and incidents involving biological hazards ($\rho = 0.83$, $p < 0.0001$),

Table 1. Distribution of occupational injuries and incidents involving biological hazards, patient falls, medication errors, other errors and near-misses reported by the workers of the unit, and by the workers of other units in the University Hospital of Udine, Northeastern Italy (2012–2013)

Variable	Occupational injuries and incidents					
	total events [n]	M/unit±SD	lower quartile	Me	upper quartile	min.–max
Year 2012 (109 units)						
occupational injuries and incidents involving biological hazards	365	3.3±6.5	0	1	4	0–52
patient falls	357	3.3±7.7	0	0	2	0–54
medication errors	188	1.7±4.0	0	0	1	0–26
other errors/near-misses, reported by the workers of the unit	337	3.1±5.5	0	1	4	0–42
other errors/near-misses, reported by the workers of other units	234	2.1±5.3	0	0	3	0–47
Year 2013 (106 units)						
occupational injuries and incidents involving biological hazards	308	2.9±7.0	0	1	4	0–62
patient falls	391	3.7±8.3	0	0	3	0–54
medication errors	172	1.6±4.1	0	0	1	0–21
other errors/near-misses reported by the workers of the unit	235	2.2±3.9	0	0	4	0–30
other errors/near-misses reported by the workers of other units	323	3.0±6.7	0	0	4	0–42

M – mean; SD – standard deviation; Me – median; min. – minimal value; max – maximal value.

patient falls ($\rho = 0.18$, $p = 0.0064$); medication errors ($\rho = 0.28$, $p < 0.0001$), other adverse events and near-misses reported by the workers of the unit where the events occurred ($\rho = 0.68$, $p < 0.0001$), and those reported by the workers of other units ($\rho = 0.69$, $p < 0.0001$). We also found significant correlations among the different outcomes, as shown in Table 2.

Table 3 presents the association of occupational injuries with the explanatory variables among all the hospital units. Table 4 illustrates the associations of outcomes 1–6 with the explanatory variables among the hospital units open to patients.

The risk of occupational injuries and incidents involving biological hazards decreased in 2013, both in the analysis including all the hospital units and in the analysis restricted to the units open to patients, although when all the units were included in the analysis this result was only of borderline significance. Non-significant decreases in patient falls, in medication errors, and in the sum of all

events were also observed. On the other hand, the risk of adverse events and near-misses reported by the workers of other units increased in 2013. In the analyses restricted to the units open to patients, the increase in the proportion of female employees was associated with significant or with of borderline significance reductions in the risk of all outcomes except for patient falls and medication errors. When all the hospital units were included in the analysis, the average annual number of sick-leave days was associated with a decrease in the risk of occupational injuries and incidents involving biological hazards. However, when considering only the units open to patients, it was no longer associated with any outcome. On the other hand, the average annual number of overtime hours in a unit was associated with a decrease in the risk of medication errors in the units open to patients. Visit requests were strongly associated with the risk of occupational injuries in the analysis including all the hospital units and with the risk of patient falls, and of other adverse events

Table 2. Correlations between occupational injuries and incidents involving biological hazards, patient falls, medication errors, other errors and near-misses reported by the workers of the unit, and by the workers of other units in the University Hospital of Udine, Northeastern Italy (2012–2013)

Variable	Pearson's correlation				
	occupational injuries and incidents involving biological hazards	patient falls	medication errors	other errors and near-misses reported by the workers of the unit	other errors and near-misses reported by the workers of other units
Occupational injuries and incidents involving biological hazards	1.00	0.25*	0.35*	0.70*	0.77*
Patient falls		1.00	0.36*	0.17*	0.21*
Medication errors			1.00	0.37*	0.28*
Other errors and near-misses reported by the workers of the unit				1.00	0.60*
Other errors and near-misses reported by the workers of other units					1.00

* $p < 0.05$.

and near-misses reported by the workers of the unit, in the units open to patients.

Compared to the services, surgical and medical units had an increased risk of occupational injuries, whereas the administrative units did not prove to be significantly

different. In the analyses restricted to the units open to patients, surgical units had an increased risk of occupational injuries and incidents involving biological hazards as compared with the other units, whereas the risk of all the other events was not significantly different from that

Table 3. Poisson regression analysis (all the hospital units) of occupational injuries and incidents involving biological hazards in the University Hospital of Udine, Northeastern Italy, and characteristics of the hospital units (2012–2013)

Variable	RR	95% CI	p
Outcome 1: Occupational injuries and incidents involving biological hazards			
year (2013 vs. 2012)	0.88	0.76–1.02	0.0906
female [% in unit] (continuous)	1.00	0.99–1.02	0.6021
average annual sick-leave days/worker in unit (continuous)	0.98	0.96–1.00	0.0165
average annual overtime h/worker in unit (continuous)	1.01	0.99–1.03	0.4344
average annual visit requests/worker in unit (continuous)	49.78	2.72–1 040.70	0.0126
new hiring > employment termination (vs. no hiring, no employment termination)	1.15	0.54–2.45	0.7202
new hiring < employment termination (vs. no hiring, no employment termination)	1.46	0.74–2.89	0.2771
new hiring = employment termination (vs. no hiring, no employment termination)	1.34	0.49–3.69	0.5673
medical unit (vs. services)	1.95	1.40–2.85	0.0001
surgical unit (vs. services)	2.64	1.83–4.02	< 0.0001
administrative unit (vs. services)	1.21	0.53–3.32	0.5534

RR – relative risk; CI – confidence interval.

Table 4. Poisson regression analysis (the units open to patients) of injuries and adverse events/near-misses in the University Hospital of Udine, Northeastern Italy, and characteristics of the hospital units (2012–2013)

Variable	RR	95% CI	p
Outcome 1: Occupational injuries and incidents involving biological hazards			
year (2013 vs. 2012)	0.80	0.69–0.92	0.0021
female [% in unit] (continuous)	0.99	0.98–0.99	< 0.0001
average annual sick-leave days/worker in unit (continuous)	0.99	0.97–1.01	0.4626
average annual overtime h/worker in unit (continuous)	1.01	0.99–1.03	0.3558
average annual visit requests/worker in unit (continuous)	1.26	0.12–13.07	0.8445
new hiring > employment termination (vs. no hiring, no employment termination)	0.87	0.49–1.57	0.6509
new hiring < employment termination (vs. no hiring, no employment termination)	0.83	0.50–1.38	0.4624
new hiring = employment termination (vs. no hiring, no employment termination)	0.81	0.39–1.69	0.5825
surgical unit (vs. non-surgical)	1.51	1.00–2.29	0.0519
Outcome 2: Patient falls			
year (2013 vs. 2012)	0.77	0.53–1.12	0.6596
female [% in unit] (continuous)	1.00	0.99–1.02	0.6460
average annual sick-leave days/worker in unit (continuous)	1.02	0.99–1.05	0.2988
average annual overtime h/worker in unit (continuous)	0.97	0.93–1.00	0.1151
average annual visit requests/worker in unit (continuous)	593.83	20.68–17 049.63	0.0002
new hiring > employment termination (vs. no hiring, no employment termination)	1.32	0.73–2.42	0.3598
new hiring < employment termination (vs. no hiring, no employment termination)	0.48	0.21–1.07	0.0734
new hiring = employment termination (vs. no hiring, no employment termination)	0.54	0.19–1.52	0.2442
surgical unit (vs. non-surgical)	0.66	0.35–1.23	0.1862
Outcome 3: Medication errors			
year (2013 vs. 2012)	0.55	0.26–1.18	0.1231
female [% in unit] (continuous)	0.99	0.98–1.01	0.4225
average annual sick-leave days/worker in unit (continuous)	0.98	0.97–0.99	0.6674
average annual overtime h/worker in unit (continuous)	0.92	0.86–0.98	0.0072
average annual visit requests/worker in unit (continuous)	0.03	0.00–10.44	0.2386
new hiring > employment termination (vs. no hiring, no employment termination)	1.28	0.41–3.98	0.6701
new hiring < employment termination (vs. no hiring, no employment termination)	0.49	0.19–1.27	0.1416
new hiring = employment termination (vs. no hiring, no employment termination)	0.41	0.15–1.12	0.0828
surgical unit (vs. non-surgical)	1.90	0.91–3.97	0.0860
Outcome 4: Other adverse events and near-misses reported by the workers of the unit			
year (2013 vs. 2012)	0.66	0.48–0.91	0.0119
female [% in unit] (continuous)	0.99	0.97–1.01	0.1989
average annual sick-leave days/worker in unit (continuous)	1.01	0.94–1.08	0.8449
average annual overtime h/worker in unit (continuous)	0.98	0.95–1.02	0.3698
average annual visit requests/worker in unit (continuous)	41.32	7.37–231.53	< 0.0001

Table 4. Poisson regression analysis (the units open to patients) of injuries and adverse events/near-misses in the University Hospital of Udine, Northeastern Italy, and characteristics of the hospital units (2012–2013) – cont.

Variable	RR	95% CI	p
Outcome 4: Other adverse events and near-misses reported by the workers of the unit – cont.			
new hiring > employment termination (vs. no hiring, no employment termination)	0.93	0.38–2.30	0.8789
new hiring < employment termination (vs. no hiring, no employment termination)	1.13	0.57–2.25	0.7167
new hiring = employment termination (vs. no hiring, no employment termination)	1.04	0.50–2.19	0.9077
surgical unit (vs. non-surgical)	0.86	0.57–1.29	0.4620
Outcome 5: Other adverse events and near-misses reported by the workers of other units			
year (2013 vs. 2012)	1.44	0.97–2.14	0.0695
female [% in unit] (continuous)	0.97	0.96–0.98	< 0.0001
average annual sick-leave days/worker in unit (continuous)	1.02	0.96–1.08	0.5085
average annual overtime h/worker in unit (continuous)	0.97	0.94–1.00	0.0656
average annual visit requests/worker in unit (continuous)	7.08	0.27–186.08	0.2457
new hiring > employment termination (vs. no hiring, no employment termination)	1.71	1.03–2.83	0.0379
new hiring < employment termination (vs. no hiring, no employment termination)	2.20	1.09–4.46	0.0280
new hiring = employment termination (vs. no hiring, no employment termination)	1.84	1.00–3.35	0.0481
surgical unit (vs. non-surgical)	0.88	0.54–1.44	0.6045
Outcome 6: Sum of all outcomes 1–5			
year (2013 vs. 2012)	0.81	0.69–0.96	0.0125
female [% in unit] (continuous)	0.98	0.97–1.00	0.0047
average annual sick-leave days/worker in unit (continuous)	1.01	0.99–1.03	0.3717
average annual overtime h/worker in unit (continuous)	0.98	0.96–1.00	0.0398
average annual visit requests/worker in unit (continuous)	24.71	3.88–157.20	0.0007
new hiring > employment termination (vs. no hiring, no employment termination)	1.38	0.67–2.85	0.3849
new hiring < employment termination (vs. no hiring, no employment termination)	0.98	0.55–1.77	0.9553
new hiring = employment termination (vs. no hiring, no employment termination)	0.92	0.41–2.05	0.8420
surgical unit (vs. non-surgical)	0.98	0.41–2.05	0.8832

Abbreviations as in Table 3.

in the other units. Compared to the units where no personnel changes took place in a given year, no significant differences in the risk of injuries and adverse events were reported in the units where new personnel was hired and/or workers stopped working, except for a significant increase in adverse events and near-misses reported by the workers of other units.

In 2013, the risk of injuries in the analysis, including all the hospital units and the risk of the sum of all outcomes

in the clinical units, was significantly reduced as compared to the previous year. However, the change in the risk of patient falls and medication errors, although strong, was not statistically significant.

DISCUSSION

This analysis identified some macroscopic characteristics of the units associated with an increased risk of occupational injuries and adverse events in an Italian teaching

hospital. In general, the clinical units had an increased risk of occupational injuries and incidents involving biological hazards than the services and administrative units. This is not surprising, taking into account the higher number of mechanical actions performed by employees working with patients, which, in turn, determines a greater opportunity to be injured. In particular, the surgical wards had a higher risk than the other units open to patients. In addition, the surgical units had an increased risk of medication errors as compared with the non-surgical ones.

A recent systematic review of medication administration errors in hospitals has shown that slips and lapses are common unsafe acts, but a variety of factors regarding local workplace, such as inadequate communication, medicine storage, perceived workload, staff health status, and patient factors, were also commonly reported [8]. Given the level of information available, we cannot identify specific factors favouring medication errors in surgical wards in our organization. However, our research indicates that structured approaches to the issue of medication errors in the University Hospital of Udine should give particular attention to surgical patients.

We found that the proportion of female employees in a clinical unit was associated with a reduced frequency of occupational injuries in that unit. It is possible that female hospital workers are more safety compliant than males, as suggested by an Egyptian study conducted among surgeons [9].

The balance between new employees and work terminations did not significantly affect the risk of most of the outcomes of interest, indicating that the hospital units are rather robust to variations in the staff size. A Canadian study has shown that younger age and shorter tenure did not increase the overall risk of occupational injuries in the healthcare sector; the young and newly hired employees turned to have an increased risk of cuts and punctures but a lower risk of musculoskeletal injuries [10]. However, in our context, the units characterized by personnel

changes had increased risks of adverse events reported by the workers of other units, even in the case of an increase in the staff size.

Errors such as procedural irregularities, patient identification, incomplete documentation etc. are most evident to workers of other units when patients, materials or documents are exchanged between the units. It is possible that the newly hired workers either make mistakes when they are not sufficiently familiar with the procedures or disrupt the pre-existing equilibrium making other workers err. Thus, it is crucial that enough training is provided to the newly hired employees and that, despite the urgency to have the new workers operative, they need to have time to practice.

When taking all the hospital units into consideration, the average number of sick-leave days in a unit was inversely associated with the injuries. This finding cannot be completely explained by the fact that workers have no opportunity to suffer from occupational injuries during sick-leave, since only 5% of the annual worktime was lost due to sick-leave in our hospital. On the other hand, assuming that the likelihood of being sick in a year is similar for employees of all hospital units, it is possible that some units have fewer sick-leave days because of greater pressure and more presenteeism (i.e., sick employees being present at work) [11]. This phenomenon, which has been significantly associated with different components of psychosocial stress [12], may also lead to decreased productivity and ineffective presence in the workplace [11].

The European Working Time Directive requires a maximum working week of 48 h and establishes rest periods [13]. A recent systematic review has shown that long working hours (> 48 h/week) could increase the risk of percutaneous injuries and road traffic accidents among physicians, but could neither assess a dose-response relation nor determine a threshold of extra hours [14].

Surprisingly, in our study, increasing overtime hours was inversely associated with the risk of medication errors

and adverse events/near-misses reported by the workers of other units. However, it is important to note that on average, each worker totalled < 10 overtime h/year (< 3 min/day). We can hypothesize that such very limited extra-work, which was very unlikely to have impact on the workers' levels of fatigue, allowed to perform some tasks with adequate accuracy. In particular, medical prescription and therapy administration, and time-consuming but important "bureaucratic" tasks (such as forms filling and documentation completion, where errors can be also detected by the workers of other units) might benefit the most from such extra-work.

Despite the imprecision of the estimates, the number of medical visits requested by the workers earlier than the scheduled date resulted strongly from and were associated with an increased risk of injuries and biological risk incidents in the analysis involving all the hospital units, and of falls and adverse events/near-misses in the analysis restricted to the units open to patients. Requests of anticipated medical examinations are rare, however, when they happen, we consider it sensible to obtain more information on the working environment in the units concerned.

The appearing decreasing trend in the risk of adverse outcomes from 2012 to 2013 seems to indicate that the measures that were already in place in the University Hospital of Udine were effective in controlling the phenomenon. However, the decrease in patient falls and medication errors was not statistically significant, and we cannot exclude that this result is due to chance alone. Continuous monitoring of temporal trend of each type of outcome is important to assess the effectiveness of preventive initiatives.

Interpretation of the results regarding patients falls deserves particular caution. In fact, risk factors for falls among hospitalized patients can be both intrinsic (i.e., personal factors, such as balance, medications, cognitive impairment, incontinence, blood pressure, nutritional status, etc.) and extrinsic (i.e., depending on a hospital

environment). Most intrinsic factors consistently emerge in the literature [15], whereas the role of extrinsic factors, especially of the non-physical ones, is less clear [16]. The results of our study, which investigated hospital unit characteristics but lacks any information on the characteristics of the patients, are likely to be confounded by the unmeasured patient-related factors. Nonetheless, the number of patient falls was moderately correlated with the number of all the other adverse events, indicating that, to some extent, falls may be influenced by the same workplace characteristics that affect the other outcomes.

Another possible limitation of this study is that the number of events resulting from incidents reporting is affected by the inclination of professionals to report hazardous situations and by the safety culture in the units. However, the fact that the number of events reported in the University Hospital of Udine is quite stable in time and very high, as compared with other Italian systems [17], makes us confident that the incident reporting system constitutes a valid source of information.

Results of this research must be also interpreted in the light of the ecological nature of the study. This means that we cannot assume that any of the associations between the outcomes and work-related factors holds for individuals. For example, despite the fact that the injuries were less likely in the units with a greater number of sick-leave days, it could be that, within the units, workers with more sick-leave days were those who actually suffered the injuries.

This study only considered a limited number of factors potentially affecting the occurrence of adverse events in a hospital setting. As an example, despite the presence of evidence of an effect of work shifts on injuries [18,19] in our hospital there were many different work schedules and thus, the shifts were difficult to summarize in a unit-level variable. Thus, residual confounding due to the unmeasured factors is possible.

Finally, this study was conducted in a single hospital. Although it might be appropriate to generalize these results

to hospitals that are similar to ours, in terms of size and cultural context, our findings may not apply to smaller hospitals or in different health systems.

CONCLUSIONS

Aggregated data were easy to obtain and provided valuable information for approaching the issue of injuries, adverse events, and work-related factors. *Ad hoc* data collection among the hospital employees and individual analysis warrant better knowledge of the problem and implementation of targeted preventive actions.

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