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Internal and External Factors Influencing Time-Related Injury Risk in Continuous Shift Work

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Time-related accident risk in shift work may be attributed to internal factors, such as fatigue, level of performance, sleep propensity, and to some external factors, like shift system, physical and social environment. Six hundred and sixty-eight events in the metallurgical industry have been analysed in terms of time of day, time on task, consecutive day of the shift block, day of the week, and season.

The injury rate was similar on all shifts but more severe accidents happened in the nighttime. Somewhat more injuries occurred in the second half of the shift, in the second part of a shift block, and in summer compared with winter. There were fewer injuries at weekends.

accident risk   shift work   time of day   day of week   season

1. INTRODUCTION

Time-related accident risk in continuous shift work reflects the combined effects of various factors of an internal (human) nature, as well as of an

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external, that is, environmental, social, or organisational, character. Because of the biological "abnormality" of night work, researchers have been interested mostly in the risks resulting from the lowered level of human performance at night, the variation of sleep propensity during the day, and an accumulation of sleep deficit being the unavoidable side effect of shift work.

It seems, however, that shift work also has social and organisational dimensions, apart from the psychophysiological one. At some times of the day, workers are under surveillance from the management (supervisory personnel) because of the latter's office hours; extremely rare, by contrast, is an inspection of work during the evening or night.

Some days of the week are naturally more calm and quiet than others, whereas some days and times are characterised by hurry and restlessness; this arises because the atmosphere of the city and home life permeates the place of work. There are also some seasons of the year when many people suffer from colds, flu, and other infections, and some months that are more suitable than others for vacations; in both cases, this results in more frequent absence and the need for replacements.

Furthermore, when the work is in a hot environment, season and time of day play an important role as modifiers of the thermal stress; whereas, with work performed in the open air, these factors could now impose very different environmental conditions (Ogiński, Ogińska, & Pokorski, 1987).

Because of this, it is hardly possible to describe the times of high risk in shift work without taking into consideration the working and social environment, both of which create external circumstances that are at least as important as chronobiological factors and mechanisms producing fatigue.

To date, analyses of accident occurrence have failed to clear up the question of the most dangerous time in shift work. This could be explained partially by the small number of publications on this matter. Carter and Corlett (as cited in Wedderburn, 1993) summarised the results of several studies conducted mainly between 1950 and 1980, which indicated the times and shifts when most industrial accidents were recorded. These studies came from various countries, branches of industry, and comprised various periods (the longest, described by Costa in 1991, comprised 15 years of accident recording in the textile industry, 1961–1975). Opinions as to the time when most accidents occurred were not consistent. The same conclusion could be drawn after reviewing the small amount of literature from recent years. Materials and methods, especially the range of independent variables under control, have differed fundamentally, which makes it impossible to draw general conclusions. In many cases, the diversity of work activities performed on various shifts might indicate that the distribution of injuries during the day reflects the diurnal distribution of dangerous work rather than circadian factors. For example, Costa (1991) pointed out that lower incidence during the night shift, observed in a textile factory, could be associated with the following factors during night hours:

- slower pace of work;
- less management control and more relaxed working behaviour;
- suspension of more risky jobs;
- closure of the medical room, as non-severe accidents were not registered.

Recently, it has often been suggested that "night work is dangerous" (see Smith, Folkard, & Poole [1994], for example). This is in accordance with the common belief—based to some extent on public opinion—which cites the disasters of ferries ("Jan Heweliusz" and "Estonia"), nuclear power plants (Chernobyl), and chemical plants (Bhopal), all which happened at night. This belief could be true when considering a single human error (or violation of rules) as resulting from internal factors only. But the matter seems to be more complex, as human performance reflects the permanent interplay of internal and external (environmental) factors. Moreover, some of these external factors vary with the passage of time; due to this, therefore, even the results of studies using the same methods may differ after a couple of years.

The present study does not claim to judge which factor contributes most to the accident risk in continuous shift work; the intentions have been only to show the complexity of underlying conditions and to try to interpret characteristic temporal trends in accidents. We are aware, however, that identifying risk factors in shift work plays a key role in undertaking the measures for increasing safety of work. The method that could be proposed to improve an individual's alertness would be quite different from that to improve the shift schedule (reorganising the work system), for example.

2. METHODS

The study was based on injury accident records collected during the past 38 years by the safety services in one of the departments in a steel plant in Cracow, Poland. This hot strip mill, in use since 1956, has been employing 800–1,200 workers, over 80% of them in a continuous shift system, enabling the plant to function 24 hrs a day, 7 days per week. The previous system (3 teams, backward weekly rotation, 56 hrs worked per week) was replaced in 1967 by the new, 4-team schedule, forward rotation, 4 days on each shift, 48-hr break after each shift block. Each team worked 42 hrs per week (40 hrs per week since 1977). Changeover times were, in both cases, 06:00, 14:00, and 22:00.

The available accidents records comprised exact time of occurrence; place of the event; kind of injury; circumstances and suspected cause of the accident; and number of days of sick leave of the injured person. On the basis of this last measurement, the injuries were classified as small (up to 3 days of sick leave), medium (requiring 4–28 days out of work), or severe (more than 28 days of convalescence). Besides, the name of the victim, age, work experience, and work post were noted in the book; however, many data were missing and this made it impossible to analyse the injury risk in terms of individual factors.

In order to get a reliable database (enabling a comparison to be made between the same people at the same work in the same system), the documentation containing over 1,500 records had to be reviewed carefully. All events that did not happen during normal work activities (e.g., outside the hall, at the bus stop, in the bathroom) or did not happen to a regular shift worker (e.g., day worker, military service worker, maintenance worker, visitor from another department) were excluded. After this selection process, 668 events remained and these have been analysed in terms of the time of day, time on task, consecutive day of the shift block, day of the week, and season of the year.

Because of a changing general attitude towards work safety in past times, considerable differences in the number of minor injuries (with no days lost) were observed. There were times when every smallest event was noted carefully in the book; there were also years when the supervisory personnel was punished, in some way, when "too many accidents" occurred in their department. For this reason, we limited some analyses to the injuries resulting in at least one day of absence from work ($n = 506$).

This way we have obtained a quite homogenous set of data concerning the shift-working population. It can be assumed that it was the same people who worked all shifts, consecutive days of the shift block, week or month of the year, even though there were the natural fluctuations in employees during this time. Workers performed similar jobs all the time, as the type of work activity and its intensity was strictly connected with the technological cycle and did not differ between shifts, days of week, or seasons. The output (tonnes of steel rolled) could differ slightly between the shifts, but one cannot observe any regular changes.

In all the statistical analyses we used the Chi^2 test to assess the significance of differences (between observed and expected frequencies of injuries).

3. RESULTS

3.1. Time of Day

The total injury rate was similar on all of the shifts, but there were more severe accidents at night (Figure 1, Table 1). The difference between morning and night shifts in the total number of injuries could be explained by a greater number of minor injuries (no sick leave) reported during the morning shift. Each shift had its own injury profile. That for the morning shift was characterised by a sharp rise in the second hour, lasting almost to the end of the shift; the afternoon shift exhibited a growing accident rate in the second half. On the night shift, the accident rate was lower during and immediately after the meal break, that is, between 02:00 and 04:00), when the work force tried to slow the tempo of work (if this was possible). Afterwards, a distinct rise was observed in the last hours.

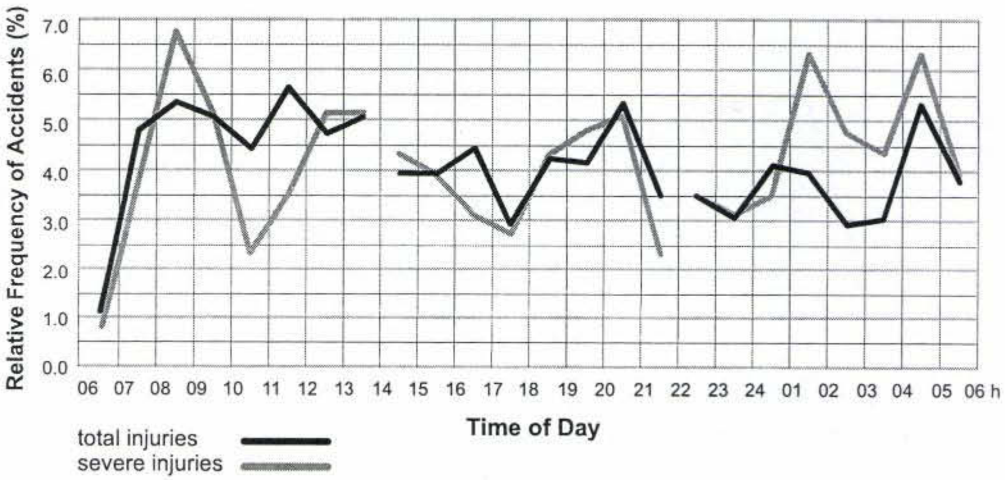

Figure 1. Percentage distribution of injuries in continuous shift work (hot strip mill, years 1968–1997, $n = 668$).

TABLE 1. Comparison of Number of Accidents on Different Work Shifts

Aspect Compared		Type of Shift		
		Morning 06:00–14:00	Afternoon 14:00–22:00	Night 22:00–06:00
Total number of injuries*	*N*	244	221	203
Injuries requiring absence from work	*N*	172	164	170
Severe injuries (> 28 days of sick leave)	*N*	82	78	91
Percentage of severe injuries	%	31	32	42
Average sick leave	days	48.8	54.6	55.9

Notes. *morning versus night shift—$p < .05$.

The frequency of severe injuries (requiring more than 28 days of sick leave) on the morning shift decreased in the second part of the shift. On the afternoon shift, the courses of "severe" and "total" injury frequencies were similar. On the night shift, by contrast, severe injuries were more common from midnight to 04:00.

The percentages of severe injuries on the morning, afternoon, and night shifts, were 31, 32, and 42%, respectively. Also, the severity of injury, as measured by the average number of days of sick leave, was slightly greater on the night shift than on the others.

Figure 2 summarises the relative frequency of accidents in 2-hr intervals, and shows clearly the shift-specific pattern.

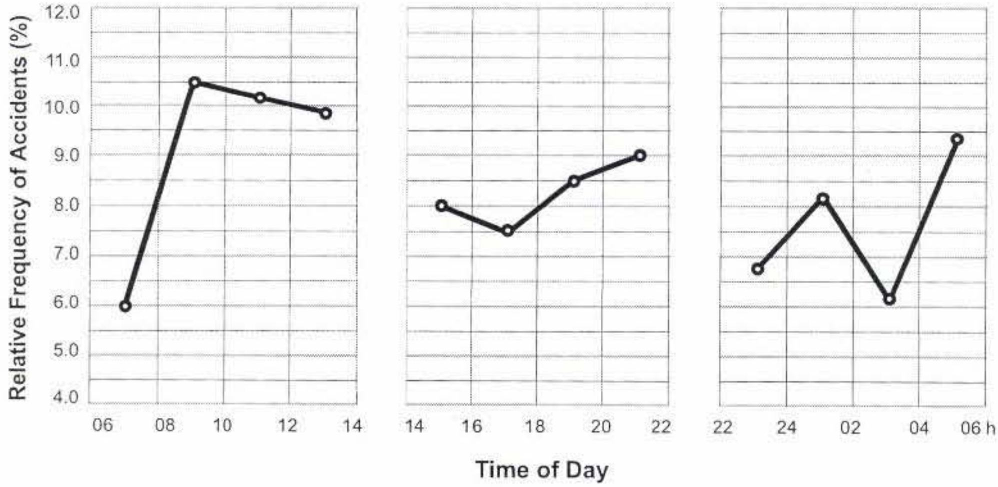

Figure 2. Shift-specific profile of accidents shown at 2-hr intervals.

3.2. Hours on Task

Regardless of the time of day, there was a lower injury rate in the middle of the shifts (time of the official meal break), and a maximum during their 7th hour; somewhat more injuries happened in the second half of the shift (Figure 3).

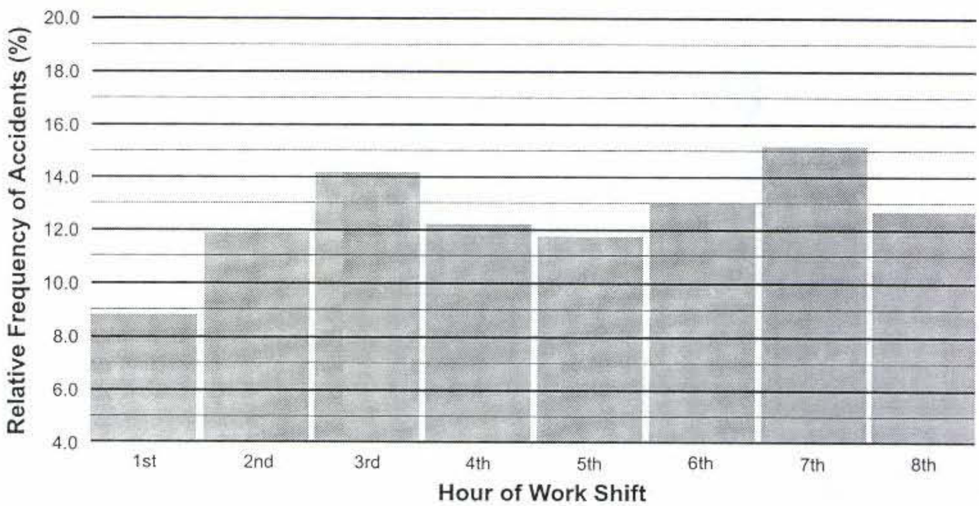

Figure 3. Percentage of injuries in consecutive hours of work shift.

3.3. Day of Shift Block

This part of study comprised the 228 cases that could be identified according to this criterion. There is a noticeable difference between the first and second halves of a shift block, this being most marked on the afternoon shift (Figure 4).

3.4. Day of Week

Figure 5 and Table 2 compare the weekly distribution of accidents in two shift schedules. In the previous, 3-team system (7-day blocks starting on Monday, 8-hr breaks between blocks), most accidents happened at the beginning of the week. In the present system (4-day blocks), the accident rate was higher in the middle of the week and significantly lower on Sundays: 77 to 88 (average 81) events from Tuesday to Friday versus 45 on Sunday ($p < .05$). The cause of the latter phenomenon might include social factors such as the generally "quiet" atmosphere on these days and the absence of maintenance and supervisory personnel.

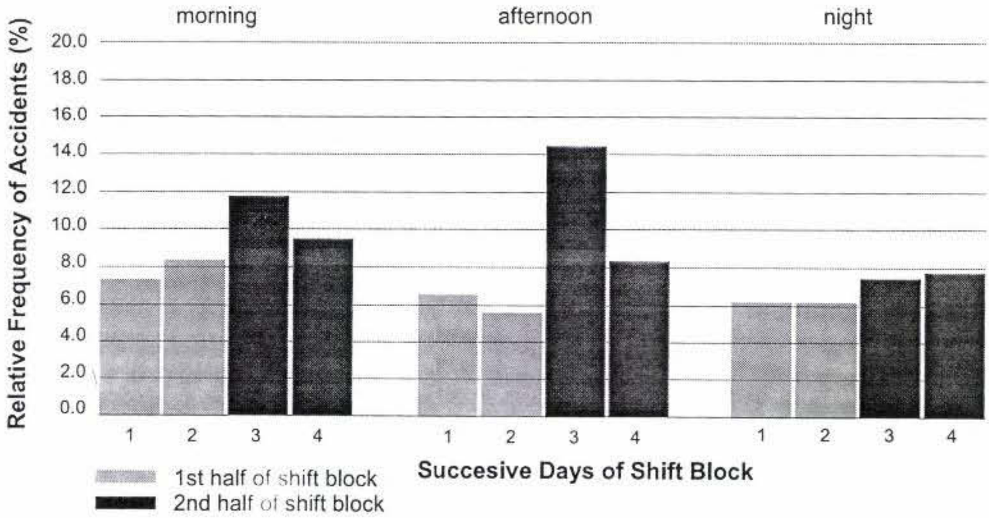

Figure 4. Percentage distribution of injuries in successive days of shift block (years 1968–1974, $n = 228$).

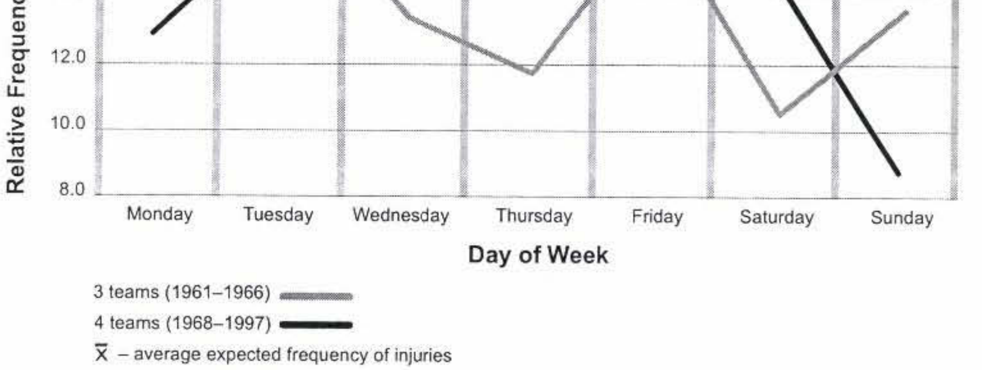

Figure 5. Weekly distribution of injuries in two shift systems (in %).

TABLE 2. Relative Frequency of Injuries on Different Shifts Throughout the Week

a) Three-team system, years 1960–1966 ($n = 293$ injuries requiring sick leave)

	Day of Week						
Type of Shift	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Morning	13.2	19.3	16.7	6.1	20.2	12.3	12.3
Afternoon	20.2	15.9	13.8	10.6	15.9	8.5	14.9
Night	18.8	16.5	9.4	18.8	12.9	10.6	12.9
Mean	17.4	17.2	13.3	11.8	16.3	10.5	13.4

b) Four-team system, years 1968–1997 ($n = 506$ injuries requiring sick leave)

	Day of Week						
Type of Shift	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Morning	12.2	20.9	12.2	19.2	15.1	12.2	8.1
Afternoon	12.2	12.8	18.9	9.8	18.3	16.5	11.6
Night	14.1	14.7	14.7	16.5	18.8	14.1	7.1
Mean	12.8	16.1	15.3	15.2	17.4	14.3	8.9

3.5. Season

Warm (May-September) and cold (November-March) seasons have been distinguished on the basis of average air temperatures in the Cracow region which are, respectively, 13.8–18.8 °C and −2.6–3.0 °C. Both April and October are characterised by a great variability and range of temperatures, with average values of about 8 °C. Archive files regarding the microclimatic conditions in the hall were not available.

Comparison of the monthly relative accident frequencies (Figure 6) shows a peak in October.

Generally, the number of accidents was significantly ($p < .05$) greater in summer than in winter (Table 3).

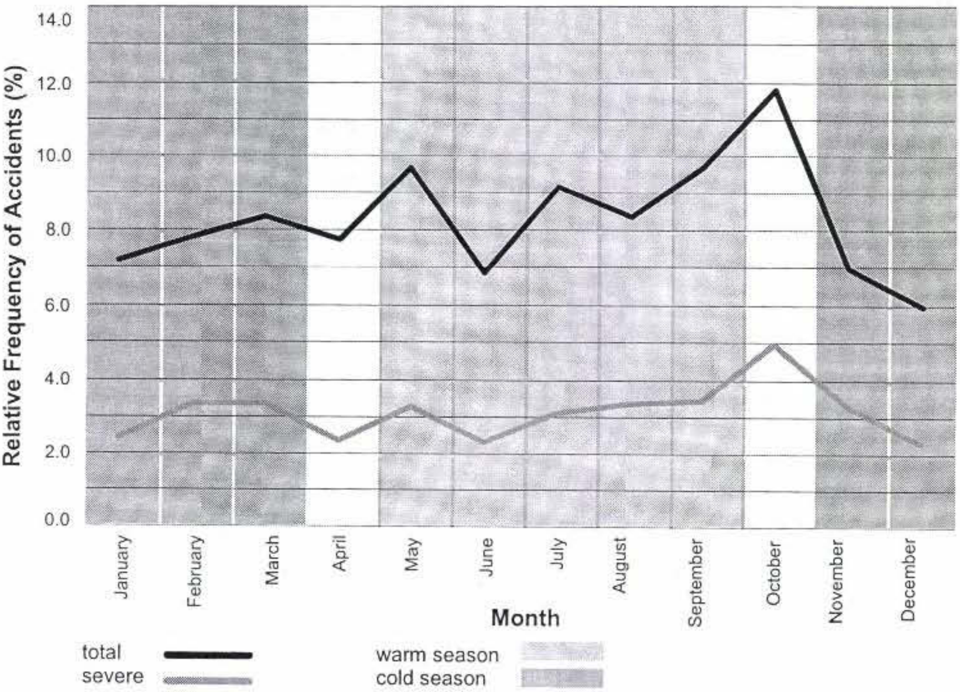

Figure 6. Annual distribution of injuries (years 1968–1997, $n = 668$).

TABLE 3. Number of Injuries Requiring Sick Leave in Warm and Cold Seasons

	Season	
Type of Shift	Warm (May-September)	Cold (November-March)
Morning	72	63
Afternoon	77	63
Night	80	57
Total*	229	183

Notes. *$p < .05$

4. DISCUSSION

4.1. Time of Day

The diurnal distribution of injuries observed by us cannot be regarded only in terms of chronobiology; rather, it is clearly the effect of an interaction between at least two internal factors (diurnal alertness and performance rhythms, and growing work fatigue) and some social or organisational factors that may create a quite different work environment at various times of the day.

Various explanations may be used to comment on shift specific patterns. The rise of accident rate during the morning shift possibly reflects both organisational and fatigue factors. Although our database comprised only regular shift workers, the presence of more workers and management personnel during the morning shift may influence their work safety by promoting additional work activities and perhaps some form of co-operation with, for example, maintenance staff; social contacts also could be important. This is in accordance with the results obtained by Ong, Phoon, Iskandar, and Chia (1987) in an iron and steel mill, where most shift workers' accidents happened between 09:00 and 14:00. Their explanation of this phenomenon was similar to ours.

The fatigue effect is, in our opinion, due to the early beginning of the morning shift (06:00), which forces a very early start to the working day (about 04:30). This is unpleasant and difficult for most of the work force, especially for those who are "evening types." It can be assumed that delaying the start of the shift to 07:00–07:30 would result in diminishing the workers' morning fatigue and improve their well-being and alertness. It is, however, not easy then to predict the possible changes in the distributions of events on the afternoon and night shifts, these being the side-effect of such an organisational intervention.

As to the afternoon shift, the growing injury rate by the end of day suggests that work fatigue, together with the tiredness that arises from the long time awake, outweigh the relatively favourable chronophysiological conditions at this time of day.

The profile of the frequency of injuries during the night shift probably reflects two factors: the tendency to slow the tempo of work, if possible, between 02:00 and 04:00 (some workers even try to nap while others are on duty if the technological process allows this); and the coincidence of a physiological lowering of efficiency, of work fatigue and of a lack of sleep in early morning hours, resulting in the peak accident rate between 04:00 and 05:00.

The difference between the total numbers of injuries reported on the morning and night shifts (244 vs. 203) approaches statistical significance; however the percentage of severe injuries is considerably greater at night. This confirms the results obtained by one of the authors (Ogiński, 1966) in the late 1960s in the same plant, as well as some data from the literature

(Andlauer & Metz, 1967; Ong et al., 1987)—injuries that occur at night are fewer but more severe. The view that nighttime accidents may be more serious is also supported by the results of Smith et al. (1994), who found the same tendency in self-paced work.

Other findings as to the relative injury risk on particular work shifts are, however, contrary to ours: The aforementioned study also showed an increase in the frequency of injuries from the morning, through the afternoon, to the night shift. However, both the work system and type of work, as well as the database (90% of the injuries were really minor) were different from those we studied.

There was also a difference in the number of injuries on particular shifts depending on the season of the year (see Table 3), and here the time-of-day effect interferes with the season's impact. It may be assumed that opposite trends (more injuries on the night shift in summer and fewer injuries on the same shift in winter) are connected with the different way of spending the day in summer and in winter (less physical activity in winter resulting in less fatigue at the beginning of the shift).

4.2. Hours on Task

The profile of accident rates in consecutive hours of a work shift in the current study (Figure 3) cannot be treated as an illustration of the relationship between accident risk and work fatigue due to the time spent at work; it could have been so had it been possible to get data regarding work shifts that had started at many different times in the day. In the present case there were only three starting times: at 06:00, 14:00, and 22:00; therefore unambiguous conclusions relating to this issue cannot be drawn. Even so, the decrease in the 4th–5th hour of work is clearly associated with the meal break, and the increase in the 7th hour could be explained by growing fatigue. The study by Nag and Patel (1998), on monthly rotating shift workers and permanent night workers employed in textile industry in India, also showed a rise in accidents reaching peak at the 6th and 7th hours in all three shifts.

The slight increase in the 3rd hour could be attributed to the so-called "2–4 hour shift phenomenon" (Tucker, Sytnik, Macdonald, & Folkard, 1999), although its nature and origin are not clear.

4.3. Day of Shift Block

The accumulation of fatigue resulted in higher injury rates (60%) in the second parts of the shift blocks. The workers of the plant, interviewed as to "the best" and "the worst" day of the shift block, assessed the first night as "the worst" and last as "the best," (Ciechanowicz et al., 1988). This assessment, related mostly to subjective well-being, did not correlate with the frequency of accidents. It seems that the individuals' state, which might reflect their alertness and performance, does not allow to predict their "accident liability" as a group.

4.4. Day of the Week

The weekly distribution of injuries points to the role of biological and social factors in determining safety at work. In the old shift system (worked until 1967), 7-day blocks, starting on Monday, resulted in the development of fatigue during the week and, particularly on the night shift, the build-up of a sleep debt. However, the opposite trend for adjustment, which should have resulted in higher alertness in the second half of the week, should also be borne in mind. Thus, the only obvious biological concern was the very short rest period between shift blocks (8 hrs). If this rest fell in the daytime, that is, between the night and afternoon shifts, this was much worse than a short rest in "normal" hours (as was the case with the changes between afternoon/morning and even morning/night shifts); that is, an inappropriate opportunity for rest might be the cause of the increased number of injuries on Mondays.

In the present system, a 4-day block starting on any given day of the week, no such "weekly" phenomenon arises. A week is a purely social notion, and so a decrease of accidents at the end of the week, particularly on Sundays, cannot be attributed to some biological phenomenon, but rather to the social meaning of a weekend. The "quiet atmosphere" of the weekend means less hurry at home (no school, very often a rest day for the spouse), less traffic on the streets, fewer passengers in trams and buses—calmness brought to work from the outside. Sundays especially are assessed as "quiet days," with less presence of supervisory and maintenance personnel and a more relaxed mood, reflecting also the relaxed home atmosphere.

Our findings did not confirm those of Monk and Wagner (1989), who considered a "heavy schedule of weekend daytime activities" as responsible for Sunday nights being the worst for accidents. The authors suggested that church and church-related social activities, which were an important aspect of life in the community studied, could be important as causing a disruption of daytime sleep on Sunday. It seems that the present community under study, the inhabitants of the Nowa Huta district of Cracow, had more opportunities to relax on a Sunday, as well as the possibility of attending mass at different times of day, not necessarily in the morning.

4.5. Season

Possible explanations for the greater incidence of injuries in the warm season, could comprise the following factors:

- climatic—higher thermal stress (the hot strip mill is a typical metallurgic department with many areas where work must be performed in hot surroundings);
- biometeorological—one can take into account more storms in the summertime, more disturbances of electromagnetic field, and more ozone in the atmosphere; all the three factors having some negative influence on human well being;
- social—a more "active" lifestyle in the warm season, which is often associated with an extra work load (agricultural activities, construction work) and results in a higher level of fatigue at the beginning of the afternoon and night shifts;
- organisational—more replacements or incomplete staff due to summer vacations.

Nag and Patel (1998), in their aforementioned study, noted higher accident rates from June to August, and lower ones in January and February, which is in accord with our observations and which was attributed by the authors to the hot temperatures in that region of India throughout the year, except for the winter months.

The distributions of accidents between shifts in both seasons do not reflect the workers' subjective assessment of the shifts in terms of those that are the most and least tiring; in summer, the morning shift seemed the best and the afternoon the worse, whereas in winter, the afternoon shift was perceived as the best and the night shift as the worst (Ogiński et al., 1987).

In summary, accident incidence in shift work exhibits fairly regular changes, caused in great measure by

- chronobiological factors (rhythms of alertness and performance);
- psychophysiological factors (level of strain and fatigue);
- social and organisational factors (rhythms synchronised by fixed social occurrences and habits, or by obligatory rules of work organisation).

Various combinations of these factors produce different results, though one group of factors is usually dominant. Whereas subjective and individual factors, regarding the specificity of human functioning during the day and the reaction to work fatigue, seem stable across the years (taking into account the continual recruitment of new workers), external (objective) factors connected with the organisation of work and its socioeconomical context, have undergone major changes in the last 38 years. These comprise some aspects of technology, the work system, the intensity of work (the output), employment, rules of work organisation, registration of occupational accidents, and social habits (e.g., the spread of TV), not to mention political transformations.

It can be assumed, therefore, that average values, derived from long-term observations of the working population and the aforementioned temporal trends, need not apply in all circumstances, or at those times in the past when changed external circumstances might have masked any effects due to human factors.

Furthermore, in the last decade, there has been a clear decrease in the total number of occupational accidents in the steel plant (about 3–5 times fewer in comparison to the 1960s), accompanied also by some changes of diurnal structure; this is a problem requiring further analysis.

5. CONCLUSIONS

With regard to the accident risk in continuous shift work, we would summarise our observations as follows:

- The injury rate is similar on all shifts.
- More severe accidents happen on the night shift.
- Somewhat more injuries occur in the second half of a shift.
- More injuries occur in the second part of a shift block.
- More injuries occur in summer than in winter.
- There are fewer injuries at weekends.

As to the fundamental question—**Is the night shift really the most dangerous one?**—this study did not produce a clear answer. It did not reveal a higher incidence of work injuries at night, and the diurnal pattern of accident risk did not follow directly the rhythms of human performance and alertness. However, the severity and frequency of severe injuries was somewhat higher on the night shift, and this may support the importance of the circadian factor for industrial safety.

Is the human factor a decisive one for time-related accident risk? No, it is clear that some external factors do affect the individual's state and influence work safety. This is also confirmed by specific weekly and seasonal fluctuations.

What are the conclusions from such an analysis for accident prevention in shift work? It is possible to summarise the most dangerous times within each shift, with regard to the 8-hr shift system, the most popular one in the industry, and some conclusions regarding the chronoergonomical modification of the work system can be drawn. Identifying the high-risk times and the underlying factors that cause them could help in devising appropriate methods of accident prevention for the individuals and the organisations concerned.

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