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Review Article

Shiftwork: Safety, Sleepiness and Sleep

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Abstract: This brief paper reviews the available published literature on shiftwork and safety that allows the relative risk of "accidents" or injuries associated with specific features of shift systems to be estimated. Three main trends in risk are discussed, namely that (i) risk is higher on the night shift, and to a lesser extent the afternoon shift, than on the morning shift, (ii) risk increases over a span of shifts, especially so if they are night shifts, and (iii) risk increases with increasing shift length over eight hours. We discuss that some of these trends are not entirely consistent with predictions derived from considerations of the circadian variations in sleep propensity or rated sleepiness, and consider factors relating to sleep that may underlie the observed trends in risk. Finally, the practical implications of the trends in risk for the design of safer shift systems are discussed.

Key words: Sleep, Shiftwork, Work Schedules, Safety, Injuries, Accidents, Sleepiness, Fatigue

Introduction

Safety is a primary concern of both workers and their employers in most shiftworking situations, particularly in transport operations and the nuclear power or chemical industries where there may be a high "public" or "environmental" risk. A number of authors have noted that many of the "headline hitting" disasters of the last few decades, such as Three Mile Island, Chernobyl, Bhopal, Exxon Valdez, and the Estonia ferry, have all occurred in the early hours of the morning. Further, investigations of these disasters have concluded that they were, at least partially, attributable to fatigue and/or human error.

This brief paper reviews the available published epidemiologic studies on shiftwork and safety that allow the relative risk of "accidents" or injuries associated with specific features of shift systems to be estimated. We argue that these trends are not consistent with predictions derived from considerations of the circadian variations in sleep propensity or rated sleepiness and consider factors relating to sleep that may underlie the observed trends in risk. Finally, we consider the practical implications of the trends in risk for the design of safer shift systems.

Trends Associated with Features of Shift Systems

There are few published studies that allow for an unbiased calculation of relative risk estimates of "accidents" and/or injuries associated with specific features of shift systems due to non-homogeneous *a priori* risk. In the few studies of industrial situations where the *a priori* risk of incidents[1] appears to be homogeneous across the 24-h day, the probability of actually reporting an incident may still vary by shift. For example, the number of workers or the level of supervision may vary over the 24-h day, as may the safety associated with the nature of the job tasks being performed.

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[1] The term "incidents" is used from hereon to refer to injuries and/or accidents.

Nevertheless, there appear to be four consistent trends in incident risk associated with features of shift systems when confounding factors are taken into account. These trends could reasonably be assumed to reflect on variations in the likelihood of errors being made by the individual operators concerned. We have detailed the studies on which these trends are based elsewhere[1–3].

The first consistent trend relates to the relative risk of incidents on the morning, afternoon and night shifts on 8-h shift systems. There are several studies based on relatively large numbers of incidents that appear to have overcome the potential confounders and in which the incident frequencies are reported separately for the morning, afternoon and night shifts[1–3]. These frequencies were pooled across the available studies to estimate the general trend. Based on these results, risk increased by 18% on the afternoon shift and by 30% on the night shift, relative to the morning shift. This finding suggests that when the *a priori* risk appears to be homogeneous across the three shifts, there is a consistent tendency for the relative risk of incidents to be higher on the afternoon shift than on the morning shift, and to be highest on the night shift.

There is also a consistent trend in the risk of incidents over successive night shifts. Seven published studies were identified that have reported incident frequencies separately for each night over a span of at least four successive night shifts[1–3]. In order to compare across these studies, the frequency of incidents on each night was again pooled across the studies, and was then expressed relative to that on the first night shift. On average, the risk of an incident was about 6% higher on the second night, 17% higher on the third night, and 36% higher on the fourth night.

One important question regarding this substantial increase in risk over four successive night shifts is whether it is attributable to the night shift, or whether this increase in risk represents an accumulation of fatigue over successive workdays. Of the seven studies, five reported the risk over successive morning or day shifts[1–3]. Similar to the previous analyses, in order to compare across these studies the frequency of incidents on each shift was expressed relative to that on the first morning/day shift. On average, the risk was about 2% higher on the second morning/day, 7% higher on the third morning/day, and 17% higher on the fourth morning/day shift than on the first shift. There was evidence that risk increased over successive morning/day shifts, but it is important to note however that the increase was substantially smaller than that over successive night shifts.

The fourth trend compares the impact of different lengths of shift on incident risk. Four recent studies have reported the trend in risk over successive hours on shift and have corrected for exposure in some manner[1–3]. All four studies report fairly similar trends to one another and by setting the mean risk in each study for the first eight hours at one, (i.e. setting the relative risk for an 8-h shift at one), hourly relative risk value could be calculated for each study. The hourly values were then averaged across the four studies to obtain an average trend. Apart from a slightly heightened risk from the second to fifth hour (see [4, 5] for a discussion of this), risk increased in an approximately exponential fashion with time on shift.

Using this trend the relative risk on shifts of different lengths was estimated by averaging the hourly values involved in any given length of shift. Variations in shift length from about 4 to 9 h had little impact on these estimated relative risk values because of (i) the exponential nature of the time on shift trend and (ii) the increased risk from the second to fifth hours. However, most importantly, we can now estimate the change in risk associated with shorter or longer shifts than 8-h. Thus, for example, we can estimate that relative to 8-h shifts, 10-h shifts are associated with a 13% increased risk and 12-h shifts with a 27% increased risk.

Finally, it appears that the trend for hours on duty does not control for the influence of breaks during a duty period, and one possible explanation for the decrease in risk after the fifth hour may be that it reflects the influence of rest breaks. A number of laboratory studies on the effects of breaks have been conducted, e.g.[6], but there appears to be only a single, recent study that has examined the impact of rest breaks on the risk of incidents[7].

This study examined industrial injuries in an engineering plant in which breaks of 15, 45 and 10 min, respectively, were given after each period of two hours of continuous work. The number of incidents within each of the four 30-min periods between breaks was calculated, and the risk in each 30-min period was expressed relative to that in the first 30-min period immediately following the break. The results indicated that risk increased substantially, and approximately linearly, between successive breaks such that risk had doubled by the last 30-min period before the next break. There was no evidence that this trend differed for the day and night shifts, or for the three successive periods of two hours of continuous work within a shift.

Theoretical Considerations

Most authors have argued that safety may be compromised at night since normally people are asleep at this time, and if

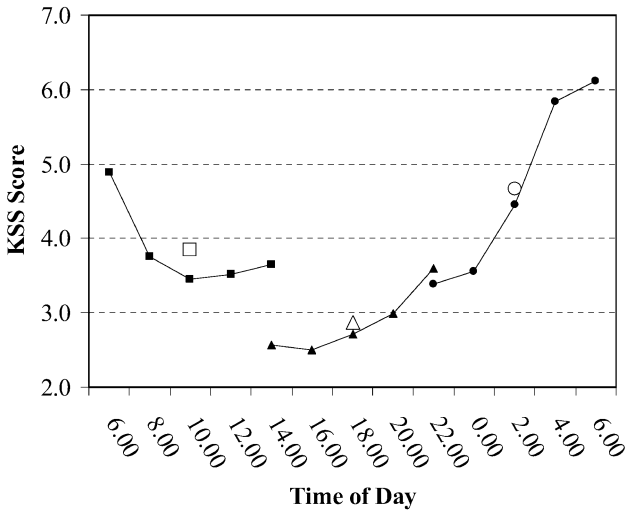

Fig. 1. The trend in sleepiness over the morning (■), afternoon (▲) and night (●) shifts and the mean values for each shift (large open symbols).

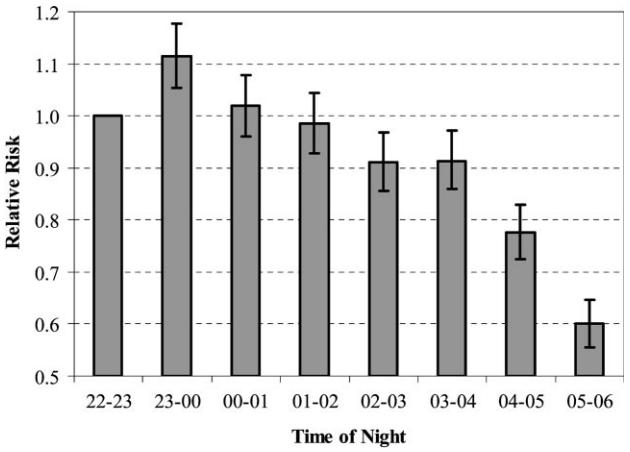

Fig. 2. The trend in Relative Risk over the course of the night shift. Error bars are 95% Confidence Intervals.

awake to work a night shift, their alertness and performance capabilities typically reach a low ebb in the early hours of the morning. Thus variations in risk are seen as reflecting on the circadian rhythms in alertness/sleepiness and performance capabilities. There are, however, two major problems with this interpretation.

First, sleepiness is usually higher on the morning shift than on the afternoon shift, despite the fact that the relative risk of incidents is lower on the morning shift (see above). A typical example of the trends in sleepiness over the three shifts is shown in Fig. 1. This figure is based on the averaged 2-hourly Karolinska Sleepiness Scale (KSS) ratings made by some 500 shiftworkers on a range of rotating 8-h shift systems, namely, continuous and discontinuous, and forward and backward rotating systems (see [8] for details). Sleepiness ratings were almost always higher on the morning shift than on the afternoon shift, and this is reflected in the mean ratings for the whole shifts (Fig. 1, large open symbols). Thus, although the increased risk on the night shift might be attributable to increased sleepiness, it is clearly not possible to account for the increased risk on the afternoon shift in this way.

An alternative explanation of the increased risk on the afternoon shift relative to the morning shift might be related to the sleep durations commonly associated with these shifts. For the 500 shiftworkers referred to above, workers slept an average of 5.9 (SD ± 1.1) hours between successive morning shifts and 8.4 (SD ± 1.3) hours between successive afternoon shifts. There is epidemiological evidence that both short and long habitual sleep duration are associated with an increased risk of mortality[9] and morbidity conditions such as diabetes[10] and coronary heart disease[11], and an increase in depressive symptoms[9]. There is also some evidence that injury risk may show a similar U-shaped relationship. Thus, for example, a case-control study[12] reported that excess sleep (9–10 h) on the night preceding a hand injury significantly increased risk (OR=2.7). Differences in the normal sleep duration between shifts cannot, however, account for the increased risk on the night shift relative to morning shift since they are typically rather similar (e.g. 6.2 versus 5.9 h in the sample described above).

The second problem is the interpretation of the increased risk on the night shift in terms of the circadian rhythm in sleepiness. This explanation would predict that risk should increase over most of the night shift as sleepiness increases (see Fig. 1), however, studies of "accident" and injury rates over the course of the night shift have consistently found a rather different pattern to this. An early study in this area by Vernon in 1923[13] reported that the frequency of surgically treated lacerations occurring in two munitions factories decreased substantially over the course of the night shift. Vernon also showed that this decreasing trend, unlike that over the day shift, could not be accounted for in terms of variations in productivity.

A number of more recent studies have shown a similar trend[1, 3] and are summarised in Fig. 2. This figure is based on the summed frequencies across all the studies and the risk at 22:00 has been set at 1. Risk decreased fairly substantially after 23:00, with only a slight suggestion of an increased risk in the early hours of the morning between 03:00 and 05:00. The general trend over the night shift is

essentially the opposite from that which would be predicted from sleepiness ratings (Fig. 1).

In summary, there are some relatively consistent trends in risk associated with features of shift systems but these are not always in line with predictions based on psychological factors such as sleepiness. In some cases it may be that we have yet to identify important psychological variables that underlie "accident" risk, or the nature of the relationship between sleepiness and risk[1]. Although the explanations for the discrepancies between risk and sleepiness are unknown, it would seem prudent to take the trends in risk seriously and to design shift systems in a manner that minimises the risk, especially in "high hazard" situations where there may be a danger to the general public or to the environment.

Practical Considerations

From a practical viewpoint, the trends in risk discussed in this paper could be used to design what should prove to be safer shift systems. Thus, for example, these trends suggest that shift length should be restricted, as should the number of successive shifts before a rest day. They also suggest that the use of frequent short breaks may reduce risk substantially. However, it is important to consider these features in combination rather than in isolation from one another. We have recently developed a "risk index" based upon a predictive model of the trends described in this paper[14]. The aim was to develop a tool that could be used to assess different work schedules with respect to their relative safety. Such a tool might also prove useful in injury and "accident" investigations to determine whether a particular injury or "accident" was at least in part, attributable to the work schedule.

In conclusion, there are consistent trends in incident risk associated with features of work schedules. In some cases, these trends are different from what would be predicted based on our knowledge of the circadian rhythm in sleepiness and clearly require further research to reveal the underlying mechanisms. Nevertheless, modelling the trends in risk may prove useful in designing safer work schedules.

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