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Working Time, Health and Safety: a Research Synthesis Paper

Philip Tucker
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Working Time, Health, and Safety: a Research Synthesis Paper

Prepared by
Philip Tucker and Simon Folkard

on behalf of
Simon Folkard Associates Ltd *

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Preface

Working time has been an important issue for the ILO ever since the founding of the organisation. The establishment of limits on daily and weekly working hours was the subject of the very first ILO Convention: the Hours of Work (Industry) Convention, 1919 (No. 1). The recent economic crisis and the Global Jobs Pact of 2009 have put working-time issues back on the agenda. At the same time, recent trends such as technological advancements enabling teleworking have contributed to the creation of a "24-hour society" where line between work and non-work time is becoming increasingly blurred. This has been coupled with a significant shift away from the "normal" or "standard" working week towards "non-standard" work schedules, for example shift work, compressed workweeks, weekend work, on-call work etc. Together these trends point to a new context for working-time policy in the twenty-first century.

In order to respond to these new challenges for working time policy and to map out the way forward for the ILO decent work agenda in the area of working time, the Tripartite Meeting of Experts on Working Time Arrangements was held in Geneva from 17 to 21 October 2011. Meeting participants included experts representing trade unions, employers' associations and governments. Prior to the Meeting, the International Labour Office had issued a report: *Working time in the twenty-first century: Report for discussion at the Tripartite Meeting of Experts on Working-time Arrangements (17-21 October 2011)*, to serve as the basis for the discussion. The report outlined contemporary trends, developments and effects with regard to different aspects of working time, such as hours of work and work schedules. This paper - alongside two other papers, one on working time and work-life balance, and another on working time, productivity and firm performance - was used as input into the discussion report for the meeting.

This paper provides a comprehensive synthesis of previous research examining the link between different aspects of working time and outcomes in terms of workers' health, well-being and workplace safety. This is a crucial issue, both because of the continuing prevalence of long hours of work, especially in developing countries, and also in terms of working time arrangements. As more and more workers engage in so-called "non-standard work schedules", there is a need for information concerning how different kinds of working time organisation can impact on workers' health and well being, in order to estimate both the short and long-term consequences for workers and employers, as well as for society as a whole. Several different aspects of working time are reviewed in this paper. First, the paper reviews amount of working hours on a daily and weekly basis, i.e. daily and weekly hours of work. Here it is argued that while long daily hours tend to be associated with acute effects of fatigue, long weekly hours tend to be associated both with acute effects of fatigue as well as chronic fatigue, generating long-term negative health effects. Second, it examines working time arrangements, i.e. the ways in which the working hours are organised. In terms of for example shift and night work, a crucial question here is to what extent different work schedules can conflict with the circadian system, that is to say a worker's biological clock. Finally, the paper also looks at newer forms of working time arrangements such as flexi-time arrangements, and concludes that providing employees with "flexibility" and control over their working time is associated with positive outcomes on workers' health and wellbeing, as well as positive organisational outcomes (e.g., increased productivity, reduced absenteeism and staff turnover).

Overall, the growing diversification in the organisation of working time raises questions about its impact on workers' health and workplace safety as well as the need for awareness of this dimension when considering workers' and employers' preferences regarding working time. At the same time, this trend is also promising in the sense that it might offer "win-win" solutions that could potentially benefit both workers and employers. It is hoped that this study will provide useful guidance regarding how to respond to new trends and developments in the area of working time and develop innovative, mutually beneficial working-time arrangements without compromising workers' health and workplace safety.

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Overview

This report reviews research examining the impact of modern working time arrangements on workers' health, well-being and workplace safety. Section 1 outlines the **theoretical framework** underpinning our analysis. It draws together the fundamental features of work schedules and the parameters around which they vary, the broad range of occupational health and safety outcomes that have been examined in the literature, and factors that underlie and / or affect the associations between the two. This paper relies heavily on measures of fatigue for three main reasons. First, unlike more chronic measures, such as those of stress, physical health and social and family disruption, fatigue is an acute response that can be pinpointed in time and hence related to specific features of a work schedule. Second, fatigue is thought to underlie many of the more chronic consequences of working time arrangements. Lastly, fatigue has been measured in a large number of studies both directly, through subjective ratings, and indirectly, through objective measures of the incidence of occupational injuries and accidents.

Fatigue is a consequence of many aspects of work. However, this paper focuses on the way in which fatigue is affected by the amount of time that an individual spends working (i.e. work hours) and the way in which that working time is arranged (i.e. working time arrangements). Sections 2 and 3 of the report focus on these two aspects separately. However, as will become apparent, they cannot be considered as entirely mutually exclusive topics, and the two strands of discussion overlap accordingly.

Section 2 considers **working hours and occupational health and safety** at two levels of analysis: first, the number of hours that are worked in a day (**daily working hours**); and second, the number of work hours that are accumulated over the week (**weekly working hours**). In both cases, the impact in terms of fatigue is at least as much about the opportunity for rest and recuperation as it is about the number of hours that are worked *per se*. It can be argued that while daily working hours tend to be more commonly associated with acute effects of fatigue (e.g. sleepiness and inattention leading to increased risk of mistakes and accidents), weekly hours tend to be associated with both acute fatigue effects and chronic outcomes such as health impairment and work-life conflict. That being said, the distinction is far from clear-cut and the overlap in both directions is considerable. The discussion of weekly working hours is further divided into two subsections that separately consider the impact of **long (>48 hours per week)** and **short work weeks (<30 hours per week)**. Contrary to what might be expected, there is evidence linking both long *and*, to a lesser extent, short work weeks to negative health and safety outcomes.

Section 3 focuses on **working time arrangements (work schedules) and occupational health and safety.** Part one examines the impact of the various features or parameters involved in defining **work schedules**. A critical issue in this regard is the way in which working time arrangements can conflict with the circadian system, which is a key component of the sleep-wake cycle. The discussion begins by considering the merits and disadvantages of rotating shifts, speed of rotation, direction of rotation, and the timing of shift start and end times. It goes on to consider non-circadian aspects of working time arrangements. Because, as noted previously, the scheduling of sufficient opportunities for rest and recuperation is a critical issue, the discussion considers the distribution of rest days within the schedule, the length of the interval between successive shifts and the scheduling of intra-shift rest breaks. This part ends with a look at the limited evidence available on the impact of split shifts (i.e. working more than one duty period in a day).

Part two of Section 3 considers **flexible working time arrangements**, i.e. the balance of control that the employer and the employee have over the employees' working time arrangements. It looks at the health and safety impacts of both "employee-led" flexibility, which are generally positive for the employee, and "employer-led" flexibility, which are generally less positive.

Section 4 summarizes recent efforts to **model the impact of working hours and working time arrangements.** Since the mid-1980s, a number of models have been developed with a view to predicting the fatigue and related risks (e.g. levels of subjective alertness, neurobehavioural performance, sleep opportunity and accident risk) likely to be associated with particular work schedules. The earlier models were largely based on a theory of the body's regulation of sleep and wakefulness. More recent, atheoretical models are simply based on established trends in fatigue and risk associated with particular features of work schedules.

The fifth and final section considers the approaches that have been adopted to **minimize the adverse effects of working hours and working time arrangements.** Earlier approaches involved prescriptive limitations on, for example, the maximum permissible number of hours of work per day or week. However, this type of approach would now appear to be of more limited value, since it fails to take account of the interaction between different features of work schedules in determining their acceptability. Consequently, there has been a move towards outcome-based regulation, e.g. ensuring that daily/weekly working hours do not cause undue fatigue. This approach is typified in the transport industry by the increasingly common Fatigue Risk Management Systems (FRMS), which aim to keep fatigue, and hence risk, within reasonable limits.

However, while FRMS may be appropriate in situations where the general public is at risk, they do little, if anything, to ensure the well-being and health of the workforce. The paper thus concludes by arguing that what is needed is the development of occupational safety and health management systems (OSHMS) aimed at minimizing the potential adverse consequences of work schedules, and it outlines how such a system might be developed within an organization.

1. Theoretical framework

The arrangement of working hours has become a crucial factor in work organization, with important economic and social consequences for both employees and employers. Not only has the link between workplace and working times been broken (for example, through teleworking), the line between working and leisure times is no longer fixed and rigidly determined by the normal working day. The general trend has been for working hours to extend into the evening, night and weekend, and for hours of duty to become more and more variable in what is sometimes referred to as the "24-hour society". In this context, shift work is an increasingly common form of working time, enabling round-the-clock activity in sectors where continuous operations are a technological necessity (e.g. chemical and steel manufacturing, power generation) or that provide vital social services (e.g. hospitals, transportation, electricity, telecommunications). The operational flexibility afforded by shift work also supports increased levels of production and the extended provision of commercial services. Shift work includes any arrangement of daily working hours that differs from standard day work. It is aimed at extending the organization's operational time from 8 hours up to 24 hours per day, by deploying a succession of different teams of workers.

Given the potential for shift work and other forms of non-standard work schedules to disrupt sleep and other aspects of well-being (see below), it could be hypothesized that the advent of the 24-hour society would be reflected in increased reports of sleep problems, stress and other health impairments. However, such a hypothesis is very difficult to test in practice. The emergence of the 24-hour society in the last couple of decades has coincided with many other societal and occupational changes. Changes in working time arrangements within society are therefore totally confounded by other factors, rendering comparisons of such historical trends all but meaningless.

According to the results of the Third European Survey on Working Conditions, only 24 per cent of the working population (27 per cent of employed and 8 per cent of self-employed workers) were engaged in "normal" or "standard" day work, that is from 7 to 8 a.m. and 5 to 6 p.m., from Monday to Friday (Costa et al., 2004). This means that the vast majority of workers is engaged in "non-standard" work, including shift and night work, part-time work, weekend work, compressed work weeks, extended working hours, split shifts, on-call work, etc. According to the Fourth European Survey on Working Conditions (Parent-Thirion et al., 2007), weekly working hours range from an average of 34 hours in the Netherlands to 55 hours in Turkey, and from a minimum of eight hours (as part-time work) to a maximum of 90 hours (as overtime work). Shift work, which includes night work, involves more than 17 per cent of the total working population, with large differences between countries (from 6.4 per cent in Turkey to 33.5 per cent in Croatia). In 2004, almost 15 per cent of full-time salaried workers in the United States of America usually worked on alternating shifts, including nights, the workers on such shifts were more likely to be men than women (16.7 and 12.4 per cent, respectively), and blacks than whites, Hispanics or Latinos, or Asians, and shift work decreased progressively with age (US Bureau of Labor Statistics, 2005). Similar statistics are sorely needed from other countries.

Extended working hours refers to working for longer than eight to nine hours per day, and 40 hours per week. According to the International Labour Organization (ILO), annual hours worked per person exceeded 1,800 (i.e. 36 hours per week for a 50-week year) in 27 out of 52 countries monitored from 1996 to 2006, and 2,200 hours (i.e. 44 hours per week for a 50-week year) in six Asian economies (ILO, 2007). In the United States, almost one third of the workforce regularly works more than the standard 40-hour week and one-fifth more than 50 hours (US Bureau of Labor Statistics, 2005). In Europe, according to the Fourth European Survey on Working Conditions, 16.9 per cent of workers in the 27 European Union Member States worked 48 hours per week or more, ranging from 11.1 per cent in Luxembourg to 32.1 per cent in Turkey (Parent-Thirion et al., 2007).

Working irregular or extended hours can have negative consequences for health and well-being owing to the stress of interference with psychophysiological functions and social life. Most studies to date have focused on shift work rather than extended working hours, although the two are sometimes confused. Some have addressed this second aspect independently, with contrasting results (Harrington, 2001; van der Hulst, 2003).

It is commonly accepted that work efficiency at night is not the same as during the day. Humans are diurnal creatures, synchronized to the 24-hour light/dark cycle; they are naturally awake and active during daylight and consequently resting and sleeping at night. This behaviour is determined by the regular oscillation of bodily functions (circadian rhythms). For example, core body temperature falls during the night when people are asleep, down to a minimum of 35.5 to 36.0°C in the early hours of the morning, and rises during the waking day to reach a maximum (acrophase) of about 37.0 to 37.3°C at around 5 p.m. This rhythmicity is controlled by an internal mechanism (the body clock), located in the suprachiasmatic nuclei area of the brain, and is influenced by environmental factors (synchronizers), such as work, activity, sleep, meals and, in particular, light exposure (Folkard, Minors and Waterhouse, 1985; Roenneberg, Kumar and Merrow, 2007; US Congress Office of Technology Assessment, 1991).

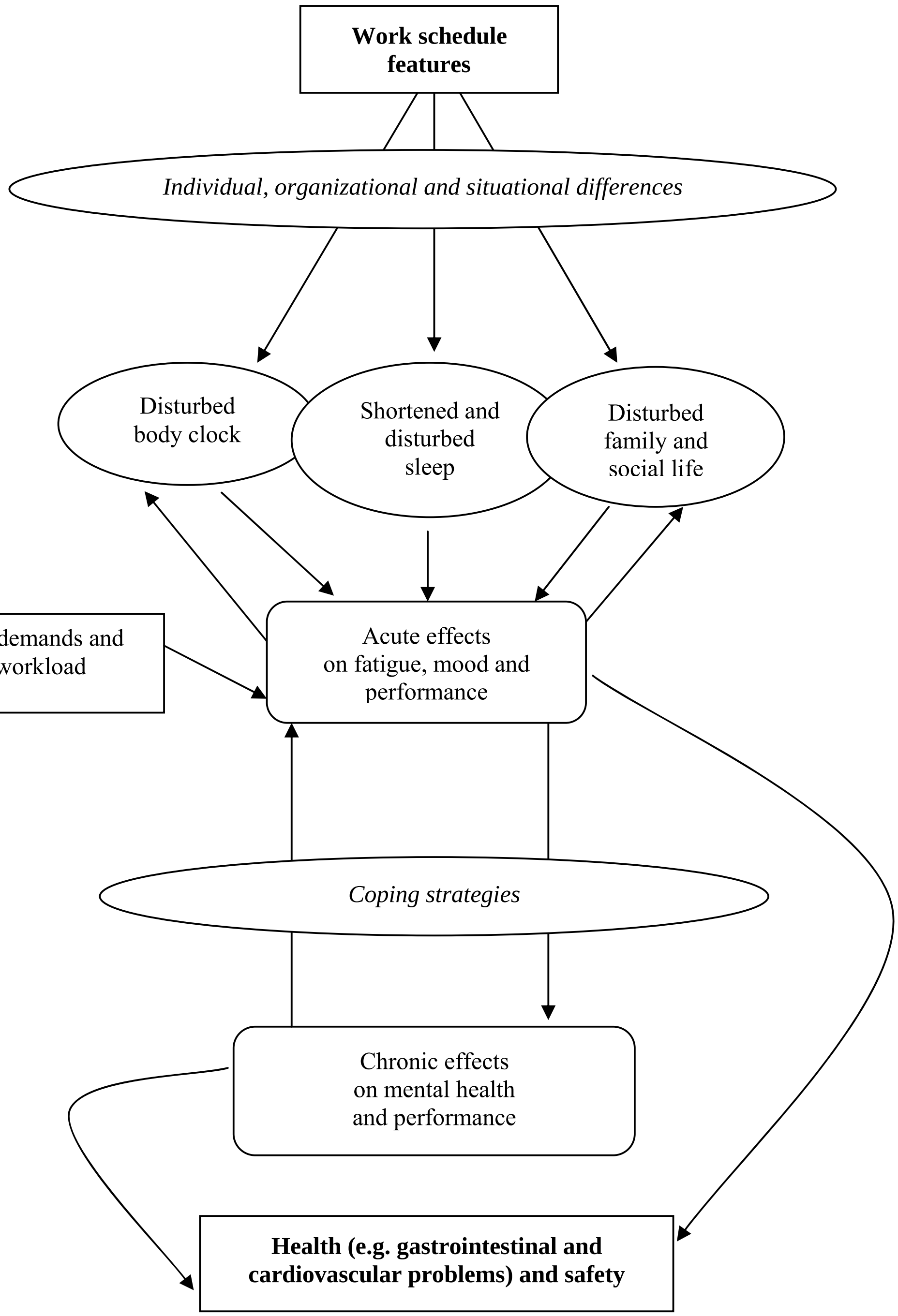
Night work forces individuals to change their normal sleep-wake cycle. It requires them to attempt to adjust to nocturnal activity by a progressive alteration in the timing of their circadian rhythms. This adjustment may be more or less complete, depending on the number of successive night shifts that are worked. However, circadian rhythms very seldom show a complete inversion. That is to say, individuals rarely achieve a level of adjustment that allows them to remain fully alert during the night and to sleep as well during the day as they normally would at night. Rather, their circadian rhythms tend to flatten out, such that parameters such as alertness show less fluctuation across the day. Moreover, the circadian rhythms of their various physiological and psychophysiological functions tend to become disassociated because of the differing rates of adjustment of the rhythms in the variables concerned. Indeed, even in permanent night workers, the vast majority show insufficient adjustment of their body clocks for it to be of any real benefit (Folkard, 2008). The general lack of circadian adjustment is due both to continuous rotation through the different shifts on most shift systems, and to the fact that most individuals try to maintain a normal, day-oriented, social and family life during their free time and on rest days.

Rhythmic disturbances may have negative effects on health and well-being. In the short term, people may suffer symptoms similar to those of jet lag, such as fatigue, sleepiness, insomnia, digestive troubles, and reduced mental ability and performance efficiency. In the longer term, rhythmic disturbances can eventually result, often in combination with other factors, in the manifestation of a wide range of complaints and illnesses (Cho et al., 2000; Colquhoun et al., 1996; Rouch et al., 2005; Waterhouse et al., 1992). A conceptual model of the aetiology of the problems that may result from the various features of abnormal work schedules is shown in Figure 1.

Abnormal work schedules may differ from one another with respect to a fairly wide range of features. Taken together, these features will influence the potential impact on sleep disturbances, the body clock, and family and social life. The most important features of work schedules in these respects are those that determine how much fatigue is accumulated, both over an individual shift and over successive shifts, and how much opportunity is provided for the dissipation of fatigue. These range from common features such as the frequency and duration of breaks within a shift, to less common features such as the duration of annual leave. They include the frequency and duration of breaks, start times and duration of shifts, start times of off-duty periods following shifts, duration of off-duty periods following shifts, number of successive shifts of a given type, sequencing of spans of successive shifts, number of successive work days, start time of a period of rest days, number of successive rest days, and the frequency and duration of longer periods of rest such as annual leave.

These features will all influence either the extent to which fatigue accumulates and/or the extent to which it is dissipated during rest periods. Many of them will also determine the extent to which individuals' body clocks and family and social life are disturbed. Other important features include the regularity or irregularity of the work schedule, the amount of notice individuals are given for when they will be required to work, the extent to which individuals can choose their own schedule or can swap work periods with one another (thus effectively modifying their rostered schedule to suit their needs), and the frequency and extent of any unscheduled overtime. The fairly substantial literature relating features of work schedules to disturbances of sleep and the body clock is reviewed in Sections 2 and 3 of this paper. Rather less attention has been paid to disturbances to family and social life, although the general finding appears to be that features of work schedules that prevent normal social and family activities, such as an evening shift, are the most problematic in this respect.

Figure 1. A conceptual model of the manner in which the various problems associated with abnormal work schedules relate both to one another and to the features of the work schedule.



A wide range of factors, including individual, organizational and situational differences, may affect the impact that work schedule features have on the various disturbances. The individual differences include gender, age and personality, whether the individuals are habitually long or short sleepers, “morning” or “evening” types, and whether or not they find it easy to sleep at unusual times or at different locations. Organizational differences are those associated with the particular organization or site and are, at least potentially, equally applicable to all individuals within the organization or at the site. They include factors such as the availability and quality of rest areas for breaks. They also include a number of factors that might loosely be considered as “stressful”, such as the psychosocial conditions at the workplace, including the level of support from colleagues and supervisors, as well as more physical conditions such as noise, vibration, heat and inclement weather.

Many of the situational differences essentially reflect on the interaction between the individuals’ personal and professional lives and will inter alia determine the “pre-shift” state of the individuals when they report for work. The classic example of a situational difference is the time it takes an individual to commute to and from work. This can have a major impact on, for example, the extent to which sleep is truncated prior to a morning shift. Commuting problems may be compounded by another potential situational difference, namely the types of activity that the individuals engage in during their rest periods. In theory, people should be able to dissipate any cumulative fatigue that may build up over successive shifts during their subsequent rest periods. However, some individuals may have a second job, and this may actually be encouraged by longer periods of rest days, while even those without a second job may have physically demanding leisure activities. The net result of these situational differences may be high levels of pre-shift fatigue at the start of a period of successive shifts.

Disturbances to the body clock, sleep and family and social life have been examined in very many studies. In all three cases, the fact that these disturbances occur is established beyond any reasonable doubt, and considerable progress has been made both in linking them to work schedule features and in determining the contributing influences of individual, organizational and situational differences. Unfortunately, most studies have treated body clock and sleep disturbances as outcome measures in their own right and have failed to examine any of the outcome measures depicted in the lower part of Figure 1. Further, although it might seem reasonable to assume that these disturbances contribute to the overall impact on health and safety, there is remarkably little evidence in the literature to support this assumption. The widespread failure of studies to examine all the levels shown in Figure 1 is indicative of the fact that it is extremely difficult to conduct such studies. The disturbances may also be important in their own right, a point that is particularly true of disturbances to family and social life, which may have a direct impact on the individuals’ quality of life.

The acute effects on mood and performance are seen as resulting not only from the features of the work schedules, via the various disturbances, but also from work-related factors such as the demands of the job and workload. These factors include the type of job being performed, the pacing and intensity of the work, and the predictability of the consequences of individual actions. A number of experimental studies of shift work and field studies have examined the impact of various features of work schedules on both performance and mood. They have typically found, for example, that both performance and alertness are lower at night than during the day, and lower on 12-hour than on 8-hour shifts (Bonnefond et al., 2006; Rosa and Bonnet, 1993). Again, however, whereas it might seem reasonable to assume that these differences underlie changes in the higher-level outcomes of safety and health, there is scant evidence to that effect. It is also important to note that the acute effects on mood and performance may also feed back into and exacerbate the various disturbances. Thus, for example, disturbed sleep may not only impair performance and mood, it may also be a consequence of such impairments.

The conceptual model proposes that an individual's coping strategies might alter the impact that lower-level disturbances have on the more chronic effects on performance, health and safety. While this suggestion is probably correct and is supported by a few studies in which individuals have been interviewed about their coping strategies (e.g. Adams, Folkard and Young, 1986), attempts to examine coping strategies by means of questionnaires have met with somewhat mixed results (e.g. Spelten et al., 1993), a reflection, probably, both of inadequacies in the coping strategy scales used and of the potentially vast differences between the types of strategy individuals adopt.

The potential chronic effects of abnormal work schedule features on mental health appear at a different level from those on physical health and safety. This is because impaired mental health may underlie some negative safety and physical health outcomes, especially those for which "stress" is considered a causal factor. Mental health effects are seen as stemming from the acute effects of work schedule features on mood, but also as feeding back into and exacerbating the latter. Thus, the well-known "vicious circle" may develop in which persistent bad moods may spiral downwards into depression. There is a reasonably consistent literature showing that abnormal work schedules, especially those involving night work, may result in increased levels of anxiety and depression, and this includes at least two longitudinal studies (Bara and Arber, 2009; Bohle and Tilley, 1989).

The final level of the model is concerned with what are arguably the most important factors, namely the physical health of the individuals concerned and the safety, not only of those individuals, but also of the general public and the environment. Much has been written on the impact of abnormal work schedules on physical health, somewhat less on the relative risk of injuries and accidents. With respect to health, a number of studies have indicated that shiftworkers whose schedules include night work show a generally higher prevalence of digestive disorders (from 2 to 5 times higher on average) than those whose schedules do not include night work (Costa, 1996; Knutsson, 2003). In addition, a number of epidemiological studies have yielded data suggesting an association between shift work and cardiovascular disease (see 3.1 below). Although the evidence linking abnormal work schedules to digestive disorders and cardiovascular disease is probably strongest, there is also some evidence linking them to other physical health problems such as cancer (Knutsson, 2003; Schernhammer et al., 2006) and maternal health issues (such as stillbirths) (Knutsson, 2003).

With respect to safety, a number of authors have pointed to the fact that the headline-hitting disasters of Three Mile Island, Chernobyl, Bhopal and Exxon Valdez all occurred at night and were all at least partially caused by human error (e.g. Mitler et al., 1988). It is very difficult, however, to determine how much of the increased risk of having an accident at a certain time of day is due to deficits in human performance, as opposed to other risk factors that increase at the same time of day. For example, if we found that air accidents were *less* frequent at night it would be very difficult to determine whether this was because fewer planes fly at night (i.e. the exposure rate), or because the air space is less congested (i.e. the hazard level), or because air crew flying skills improve (i.e. changes in performance capabilities). Unfortunately, most of the literature on the impact of work schedules on accident and injury rates suffers from similar problems of unknown exposure rates and hazard levels. That is to say, many studies have presented data showing increased accident risk associated with certain times of day or with certain types of schedule, but in most cases they have been unable to dissociate the effects of impaired human performance from the effects of increased exposure and increased hazard level when attempting to identify the underlying cause of the heightened risk.

A few studies have nevertheless been published in which exposure rates and hazard levels appear to be constant and any variation in injury frequencies can thus be reasonably assumed to reflect variations in the performance capabilities of those concerned. These studies tend to agree that the risk of injury: (i) is higher at night than during the day (by about 25-30 per cent); (ii) rises in a fairly linear manner over at least the first four successive shifts, with a greater increase on night shifts than on day shifts; and (iii) is higher on 12-hour than on 8-hour shifts (by about 25-30 per cent; see Folkard and Tucker, 2003). These findings have been shown to be relatively consistent across studies and have been used to develop a "Risk Index" that can be used to predict the relative risk associated with any given work schedule (see below and Folkard and Lombardi, 2004; Folkard, Robertson and Spencer, 2007).

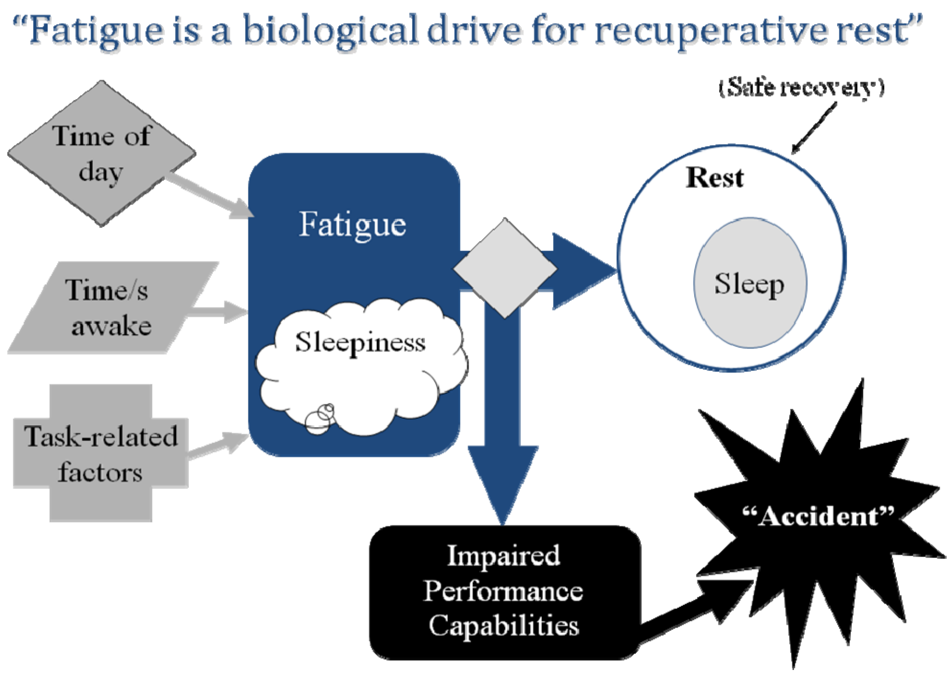
The increased risk associated with some features of work schedules is thought to result from fatigue, which has been identified as a contributing factor for accidents, injuries and death in a wide range of settings. These settings include transport operations by road, air, rail and sea, as well as various occupational settings (e.g. industrial, hospitals, emergency operations, law enforcement). Fatigue effects such as slower response times, attention deficits or failure to suppress inappropriate strategies have been identified in many high-profile accidents (Mitler et al., 1988).

In many countries, fatigue has been identified as a contributing factor in a significant proportion of road transport accidents (Dobbie, 2002; Horne and Reyner, 1995; Philip et al., 2001). Estimates of the role of fatigue in crashes can vary considerably, depending on the severity and circumstances of the crashes examined. Typical ranges cited are from 1 to 3 per cent of all crashes to up to 20 per cent of crashes occurring on major roads and motorways (Horne and Reyner, 1995). It is generally agreed that any percentages based on crash data underestimate the true magnitude of the problem, since the evidence for fatigue involvement in crashes is often questionable, being based on criteria that exclude other factors rather than identifying the definite involvement of fatigue.

There is no clear definition of fatigue. We view fatigue as a hypothetical construct which is inferred because it produces measurable phenomena even though it may not be directly observable or objectively measurable. Fatigue, as a construct, links a range of factors that presumably cause fatigue with a number of safety-related outcomes. The link between experiences - such as a long period without sleep - and crashes or accidents is based on the projected effect of fatigue. Fatigue is the mechanism by which the link exists.

Nor is there much agreement on existing definitions (Desmond and Hancock, 2001; Noy et al., 2011). However, for the purposes of this paper we adopt the definition used by Williamson et al. (2011), namely that fatigue is "a biological drive for recuperative rest". This rest may or may not involve a period of sleep, depending on the nature of the fatigue. We consider that fatigue can take several forms, including sleepiness as well as mental, physical and/or muscular fatigue, depending on the nature of its cause. On many abnormal work schedules, it seems probable that sleepiness and mental fatigue will be the most important forms of fatigue. Figure 2 illustrates how the result of the development of fatigue and sleepiness may be either a safe recovery or a decrease in performance capability leading to an adverse safety outcome (from Williamson et al., 2011). This paper examines the impact of working hours and working time arrangements on the various factors noted in terms of increased fatigue, including circadian influences and the homeostatic factors of sleep loss and time since last sleep. These are shown on the left-hand side of the model depicted in Figure 2. The model conceptualizes the experience of fatigue and sleepiness as providing the drive for restorative rest and sleep (or safe recovery, as shown on the right-hand side). To the extent that this drive remains unsatisfied, the capacity to perform is impaired and this in turn heightens the risk of adverse safety outcomes. Increasing levels of fatigue and sleepiness reduce performance capacity with, of course, falling asleep having the most extreme effects.

Figure 2. A conceptual model of the relationship between fatigue and safety (from Williamson et al., 2011).



This paper concentrates on direct subjective ratings of fatigue and on the indirect, but objective, estimates of fatigue provided by the incidence of occupational injuries and accidents. This is primarily because of the methodological challenges of attempting to examine the impact of working hours and schedules on chronic measures. These challenges can be illustrated with reference to a survey conducted of more than 2,000 aircraft maintenance engineers in the United Kingdom, which measured both the "normal" hours worked per week (including overtime) and the reported prevalence and incidence of various health problems and illnesses (Folkard, 2002). As hypothesized, the incidence of minor infections grew as work hours increased. However, contrary to what was expected, the incidence of cardiovascular symptoms fell as work hours increased. This finding probably reflects a self-selection bias of the fittest workers into longer working hours (i.e. a healthy worker effect). In addition, age was negatively correlated with normal working hours, such that, on average, older workers worked fewer hours per week. Thus, any association between working hours or schedules and many chronic (or long-term) health outcomes may be confounded by age, and in many cases these chronic health outcomes require long induction and latency times to emerge. There are some health effects and symptoms that are of a more acute nature and that could be examined with respect to the impact of various work schedules. These effects include headaches, stomach aches and muscular pains, but it is unusual for records of such symptoms to be kept by employers. In practice, therefore, it is not possible to relate these outcomes to features of work schedules.

The second reason is that fatigue is thought to underlie many of the more chronic consequences of working hours and schedules, such as psychological and physical health problems (see Figure 1). Thus, it is at least arguable that if we manage to minimize fatigue we will also reduce the more chronic adverse consequences of working time and schedules. The final reason for concentrating on measures of fatigue is simply that, because of its acute nature, fatigue can be pinpointed in time and hence related to the specific features of work schedules in well-controlled studies. Fatigue has consequently been measured in a very large number of studies, either directly through subjective ratings, or indirectly through objective measures of the incidence of occupational injuries and accidents.

In sum, the adverse consequences of working hours and work schedules are seen as stemming from disturbances to individuals' sleep, biological rhythms and family and social life. The extent of these disturbances will depend not only on the precise nature of the working hours and work schedule but also on a number of moderating factors, such as situational, organizational and individual differences. The immediate consequences of these disturbances are various, but include impaired mood and performance. Individual coping strategies will determine the extent to which these result in longer-term consequences such as physical and psychological ill health, and reduced safety. Many such consequences stem from increased levels of fatigue, which may be viewed as a biological drive for recuperative rest.

2. Work hours and occupational health and safety

The longer people work during the day, the more likely they will begin to experience fatigue at some point during that duty period. In most cases, these feelings of fatigue will persist, and likely increase, until work is ended. A long work day means that the window of opportunity for rest and recovery before returning to work the next day is reduced. Thus, if another duty period is scheduled for the next day, the individual will return to work less rested than if the previous work day had been shorter. If this same pattern of long work periods and inadequate recovery is repeated day after day, throughout the week, and perhaps also from one week to the next, the result is likely to be a substantial accumulation of fatigue and associated problems (e.g. impaired well-being). Thus long work duty periods are particularly problematic when there is inadequate opportunity for regular rest and recovery between duty periods. This highlights the need to consider the length of an individual duty period in the light of the accumulated number of hours that are worked during the week. There is an important distinction to be drawn between working several long duty periods in a week (e.g. working 5 or more days per week with overtime), such that the overall weekly hours are high and rest opportunities are limited, and compressing the normal weekly work hours into fewer longer duty periods (i.e. extending daily working hours). The two issues are therefore considered separately below, beginning with the latter.

It would tempting to assume that, as a corollary of the above, short weekly working hours (i.e. <30 hours per week) will be associated with lower levels of fatigue and hence generally benign impacts on health and safety. In practice, while the evidence base is very limited in this regard, research findings suggest that this may not always be the case.

2.1 Daily working hours

Compressing the work week into fewer longer shifts (e.g. 12-hour instead of 8-hour shifts) tends to be popular with workers, who appreciate the extended periods of time off and the reduced number of commutes. However, longer shifts require the work effort to be sustained over an extended period without substantial rest. This could, in theory, result in fatigue accumulating to unsafe levels towards the end of the shift.

Sleep and sleepiness

Comparisons of the effects of 8- and 12-hour shift systems on sleep and sleepiness have produced mixed findings (Tucker, 2006). Our own research found that measures of sleep and sleepiness outcomes tended to vary between favouring either 8- or 12-hour shifts systems depending on the time of day, but with few substantial differences being observed at any point (Tucker, Barton and Folkard, 1996; Tucker et al., 1998a, 1998b). This suggested that, overall, 12-hour shifts are no more problematic than 8-hour shifts, and several other studies have reported either neutral or beneficial effects of 12-hour shifts on sleep and sleepiness (Duchon, Keran and Smith, 1994; Lowden et al., 1998; Mitchell and Williamson, 2000; Williamson, Gower and Clarke, 1994). Where improvements were observed, this seemed to be because compressed work weeks often allow for a greater number of nights of "normal" sleep over the cycle. However, sleepiness may be higher at certain times of day, particularly towards the end of the night shift (Rosa, 1991; Rosa and Bonnet, 1993; Rosa and Colligan, 1989). Moreover, 12-hour shifts may be associated with poorer sleep in highly demanding work environments (Iskra-Golec et al., 1996). In many studies, shift length was confounded with other factors, often in a manner that favoured 12-hour systems. For example, in the above studies, 12-hour systems were compared with 8-hour systems that variously featured short intervals between shifts (i.e. so called "quick returns"; Lowden et al., 1998), earlier change-over times (Rosa, 1991; Rosa and Bonnet, 1993; Rosa and Colligan, 1989) or irregular shift patterns (Williamson et al., 1994).

Health, well-being and satisfaction

The lack of a clear and consistent association between compressed work weeks and sleep problems is paralleled by a lack of evidence linking them with negative physical and psychological health outcomes. Indeed, some studies have reported positive changes in health outcomes associated with longer shifts. However, in many cases the comparisons between longer and shorter shift durations were confounded by other variations in other schedule characteristics (e.g. speed of shift rotation, shift change-over times - see Section 3). It seems likely that the relatively benign effects of compressed work weeks on health are contingent upon well-designed schedules that involve rapidly rotating shifts (i.e. schedules that minimize circadian disruption – see Section 3). Negative health outcomes are most likely to be associated with extended shifts in combination with either high work demands (e.g. Iskra-Golec et al., 1996) or regular overtime (e.g. Caruso, Lusk and Gillespie, 2004). Such schedules are likely to maximize the mismatch between need and opportunity for recovery.

A further caveat to the apparently benign impact of extended shifts is that because employees often tend to prefer working fewer longer shifts each week, this may bias the reporting of health problems in favour of such working time arrangements. In this vein, it is interesting to note that two studies whose methodologies were less likely to alert respondents to the comparative nature of the research (Martens et al., 1999; Yamada et al., 2001) both found that compressed work weeks had a negative impact on health. Positive attitudes towards compressed work weeks may explain why such schedules have been linked to improved rates of staff turnover, while the majority of studies find that absenteeism rates are unaffected (Tucker, 2006).

There is some evidence from studies of nurses of an association between extended shifts and incidence of musculoskeletal disorders (Lipscomb et al., 2002; Trinkoff et al, 2006). Trinkoff et al. reported that, with the exception of back disorders, the associations were largely explained by physical demands.

Gender

Only a very few studies have examined gender differences in the impact of compressed work weeks. A study of nurses (predominantly women), air traffic controllers (men and women), police officers (men) and police force workers (predominantly men) found that women evaluated the impact of compressed work weeks on non-work activities no differently than men (Kaliterna and Prizmic, 1998). Nevertheless, for women in particular, the advantages of compressed work weeks may be outweighed or negated by other aspects related to the "double burden" of trying to combine paid work and unpaid work (i.e. domestic and caring roles).

A number of studies of female nurses have reported that compressed work weeks have a negative impact on non-work activities such as domestic and caring duties (Blanchflower, 1986; Kundi et al., 1995). It has been suggested that compressed work weeks may be less popular with women, who may experience greater disruption to child care when working extended shifts (Armstrong-Stassen, 1998). This may be because, in most cases, child care is a daily activity, i.e. it has to be undertaken on both work days and rest days. For individuals in this situation, the advantage of having more days away from work during the week may be outweighed by the reduction in free time (e.g. for child care) on work days. Fast and Frederick (1996) found that women experienced more time-stress on compressed work weeks than men. They attributed this to the fact that many household tasks such as meal preparation and child care cannot be easily delayed or rescheduled. It was suggested that working longer days makes these times of peak stress – morning and after work – even more stressful. They also speculated that women working compressed work weeks may be under greater pressure to accomplish more household tasks during their additional rest days. As many household tasks are continuous and repetitive, this makes it difficult to say that such work is finished. A study of the failed implementation of compressed work weeks in Singapore reported that among various complaints from workers, mothers found it more difficult to juggle the roles of worker and homekeeper when working 12 hours a day (Kogi, Ong and Cabantog, 1989).

Performance

There is no clear evidence that extended shifts have an overall adverse effect on job performance (Tucker, 2006), but there is some suggestion that they may impair performance in certain occupational settings (e.g. nursing; Fitzpatrick, While and Roberts, 1999; Geiger-Brown and Trinkoff, 2010; Reid, Robinson and Todd, 1993; Todd, Reid and Robinson, 1991). Twelve-hour shifts can lead to improved shift handovers (Wedderburn, 1996), although some workers may have greater problems readjusting to the work environment on the first shift back after an extended period of rest (L. Smith, Folkard et al., 1998).

Safety

While a well-designed schedule featuring long shifts should not lead to *chronic* sleep deprivation, so long as the job is not too demanding, there may be problems of *acute* fatigue at certain points within the shift cycle. A meta-analysis of occupational injury and accident data collated from three previously published studies of national accident statistics identified a substantial increase in risk in the last three hours of a 12-hour shift, after correcting for exposure (Folkard and Tucker, 2003). Risk in the twelfth hour on shift was more than double the average hourly risk during the first eight hours. Longer shifts (particularly those of 12.5 hours or longer) have also been linked to an increased risk of drowsiness at the wheel and driving accidents / near–misses on the journey home from work (Scott et al., 2007).

The problem with the above studies is that they do not explicitly distinguish between the effects of extending shift length while keeping weekly work hours constant (i.e. compression of the work week) and the effects of extending the length of the work week (i.e. working more hours per week). Hence it is unclear whether increased risk towards the end of an extended shift is the result of a single shift being worked, or whether the trends partly reflect accumulated fatigue that results from having limited time off during the week. In this regard, an epidemiological study of medical worker injuries reported that while working more than 60 hours per week was associated with increased risk, working 12 or more hours per day was not (Dembe, Delbos and Erickson, 2009). Conversely, other studies in medical settings have reported increases in risk associated with both extended shifts (durations of 12.5 hours or longer) and longer weekly work hours (Rogers et al., 2004; Scott et al., 2006). However, in these studies it was unclear whether the two effects were entirely independent of one another, as the researchers did not explicitly control for the number of hours worked per week when comparing longer and shorter shifts.

Conclusion

In summary, the findings regarding the impact of extended shifts on fatigue, well-being, performance and safety are inconsistent. This may be due in part to differences in the nature of the occupations or job-tasks being undertaken by the subjects of the studies (L. Smith, Folkard et al., 1998). For example, unstimulating work environments, monotonous tasks and the requirement to sustain attention all increase the likelihood of performance decrement over prolonged periods, although this may not be due to the development of fatigue *per se* (Williamson et al., 2011). Long (i.e. 12-hour) shifts may cause increased sleepiness in situations with a high workload, inadequate staff resources, insufficient rest breaks or extended commuting time (Rosa, 1995). In addition, the successful implementation of extended shifts depends on how those shifts are arranged, for example, in terms of start and finish times (Tucker et al., 1998a, 1998b), the distribution of rest days (Tucker et al., 1999) and the distribution of rest breaks within the shifts (Tucker, 2003; see Section 3). It is therefore difficult to specify a universally applicable recommendation for maximum shift duration. Nevertheless, on the balance of available evidence, and especially in the light of the observed increase in accident risk with extended time on shift, it is recommended that shifts should not be longer than 12 hours in duration.

2.2 Weekly working hours

2.2.1 Long weeks (>48h per week)

We noted previously that, unlike schedules that compress the work week into fewer longer shifts, schedules with very many hours worked per week may involve long shifts and limited opportunity for recovery during free time. Workers will experience a greater need for recovery, due to their prolonged exposure to work demands, together with reduced opportunity for achieving that recovery. As a result, long weekly work hours may have a negative influence on health, performance and safety outcomes.

Sleep

Consistent with the above suggestion, evidence from the Whitehall II Study (an epidemiological study based on data collected over an 11-year period in a large sample of middle-aged British civil servants) indicates that long weekly work hours are associated with shorter and more disturbed periods of sleep (Virtanen et al., 2009a). This is likely to reflect the restricted time available not just for sleeping but also for relaxation during leisure time. Being unable to fully relax and unwind can lead to increased sleep disturbance (Viens et al., 2003).

Health, well-being and satisfaction

It has been suggested that the impairment of recovery between work days may underlie many of the health problems that are associated with long weekly work hours (Geurts and Sonnentag, 2006). Sparks et al. (1997) conducted a meta-analysis of research into the health effects associated with long working hours. They concluded that there was a link between hours of work and both physical and psychological ill-health and that the strengths of the link was influenced by a wide range of intervening factors. At around the same time, Spurgeon et al. (1997) published a review of both health and safety considerations. They concluded that there was sufficient evidence to raise concerns about the risks of long working hours. However, the relationships identified were generally quite weak, with many inconsistencies between the findings of individual studies.

In an attempt to address the issue of variable findings, van der Hulst (2003) conducted a systematic review of studies published since 1996 that examined the relationship between long working hours and health, taking the methodological quality of the studies into account. Most of the studies reviewed found either no association between long working hours and adverse health outcomes, or an unexpected association. She identified positive associations between long working hours and rates of mortality, cardiovascular disease, non-insulin-dependent diabetes, risk of disability retirement and some specific measures of self-reported physical health and fatigue. The findings regarding psychological well-being were mixed. Weak positive associations were found between long working hours and physiological outcomes such as cardiovascular (heart rate and variability), biochemical (e.g. cholesterol) and immunological (immunoglobulin, T-helper and T-suppressor cells) indices. She concluded that the evidence tended to support an explanation of the link between long working hours and impaired health in terms of physiological changes (cardiovascular and immunological parameters), rather than changes in health-related behaviour (i.e. reduced sleep). Although this would appear somewhat to contradict the position subsequently taken by Geurts and Sonnentag (2006), van der Hulst conceded that the evidence on which she based these particular conclusions was weak.

Subsequent reviews by Caruso and colleagues (2006; 2004; 2008) reached broadly similar conclusions. They identified higher risks of sleep deprivation, poor recovery from work, decrements in neurocognitive and physiological functioning, illness, adverse reproductive outcomes, delayed marriage and child bearing, obesity in children, reduced productivity, work errors and injury, and musculoskeletal disorders.

More recently, research based on the Whitehall II Study has identified an association between long working hours and incident cardiovascular disease (Virtanen et al., 2009b). Working 3 to 4 hours of overtime per day was associated with a 1.56-fold risk of coronary heart disease, after taking into account the effects of demographic factors and several other known risk factors such as smoking, high cholesterol, hypertension, work stress, sleep length, depression and anxiety. There was, however, some evidence to suggest that the relationship might be partly accounted for by Type A behaviour (an adverse behavioural style in response to environmental stress characterized by a chronic incessant struggle to achieve more and more in less and less time). That is to say, Type As may have a greater tendency to work long hours, while at the same time be more susceptible to cardiovascular disease as result of other behavioural tendencies. There was also some suggestion in the data that decision latitude (i.e. the degree of control and autonomy people have over the way they do their jobs) might affect the strength of the link. Physical fitness may be another influencing factor, as indicated by a recent study involving a 30-year follow-up of middle-aged men (Holtermann et al., 2010), who reported that moderate physical fitness offered a degree of protection from the effects of long working hours on the incidence of ischemic heart disease.

A number of other variables that influence the strength of the relationship between long working hours and health have also been identified in recent years (e.g. Tucker and Rutherford, 2005; van der Hulst and Geurts, 2001; van der Hulst, van Veldhoven and Beckers, 2006). Although the findings were not entirely consistent with each other, taken together, they provide some evidence that the strength of the relationship between overtime and health is influenced by third factors such as autonomy, high job demands, external pressure to work overtime, and low rewards. They also suggest that long working hours do not always have detrimental effects on health, for example when the employees have control over their schedules and enjoy high rewards, low demands and an absence of pressure to work overtime. This is in line with other findings indicating that employees who enjoy their work (e.g. managers) may actually be motivated to work overtime (Taris et al., 2006). It thus seems likely that long working hours are not intrinsically harmful in many cases. Rather, the harm often results from other factors that tend to coincide with long working hours, e.g. heavy work load, sleep disruption (Sato, Miyake and Theriault, 2009) and the inability to unwind and detach from work (Taris et al., 2008). However, it is important to remember that while the well-being of some individuals may be unharmed if they are allowed to work overtime, the risk of an increase in fatigue-related errors remains even when the overtime is voluntary (Olds and Clarke, 2010).

Returning to the Whitehall II study, Virtanen and colleagues also identified an association between long working hours and a decline in cognitive function, while taking into account the effects of other factors known to affect cognitive function (Virtanen et al., 2009c). They were unable conclusively to identify what connected the two outcomes, or indeed what direction any possible causal connection might take. However, they pointed out that mild cognitive impairment predicts dementia and that the effect observed on cognitive function was of a similar magnitude to that observed for smoking.

Fatigue and performance

As noted from the studies cited above, long working hours are commonly associated with fatigue and sleepiness at work. However, the picture is not entirely consistent, with some studies finding either no association (e.g. Beckers et al., 2007; Beckers et al., 2004) or even negative associations (Åkerstedt et al., 2004). The first two studies attributed the lack of positive associations to the relatively moderate levels of overtime being studied, while Åkerstedt et al. attributed the negative association to selection effects (i.e. only healthy and resilient workers choosing to work overtime). Long weekly working hours generally result in particularly high levels of sleepiness at work when combined with night work (Son et al., 2008; Tucker et al., 2010).

Spurgeon et al. (1997) noted that, at the time of writing, there had been few systematic investigations of performance effects and that the most reliable evidence derived from studies conducted in the early part of the twentieth century. On the basis of the scarce information that was available, they concluded that longer working hours tended to be associated with lower productivity and higher absenteeism. It would seem that such evidence remains relatively rare today. An earlier study of automotive workers found that overtime was significantly associated with impaired performance on several tests of attention and executive function (Proctor et al., 1996). Two recent studies based on data collected in a heavy manufacturing setting (H. Allen, Slavin and Bunn, 2007; H. Allen et al., 2008) examined health-related impairments of work performance but found only very limited associations with long weekly working hours. Nevertheless, some particularly robust and compelling evidence of an association between long working hours and performance comes from recent studies of medical errors (see below). Inconsistencies between findings are hard to account for conclusively, particularly given the limited number of studies. However, it seems likely that, as with health, the strength of the association between long weekly hours and performance is influenced by a range of factors, e.g. occupation, the amount of overtime being worked and methodological factors that differentiate the studies.

Safety

A survey of 110,236 job records (Dembe et al., 2005) identified a strong positive association between weekly working hours and risk of occupational injuries and illness. Working at least 60 hours per week was associated with a 23 per cent higher risk (as compared to working less than 60 hours), after taking into account other known risk factors such as age, gender, occupation, industry and region. The conclusion was that long working hours are not more risky simply because they are concentrated in more hazardous occupations, or because people working longer hours spend more time at risk of acquiring a work injury. Further compelling evidence of the cumulative effects of long working hours over the course of a week was provided by Vegso et al. (2008). Using a company's accident records, they compared employees' working hours in the week prior to injury with a control week in which they were not injured. The design, which also included a comparison with a matched control group of uninjured workers, eliminated a wide range of potential confounding factors (i.e. individual differences and temporal factors that might otherwise account for an association between working hours and risk).

It was found that individuals who worked more than 64 hours in the week before the shift in which the injury occurred had 88 per cent excess risk compared to those who worked 40 hours or less.

Historically, long weekly hours have been a common feature in health-care settings. A small number of recent intervention studies have demonstrated that doctors make fewer errors following reductions in both shift length and the overall number of hours worked per week. A study in the United States involved the replacement of a system of 24-hour on-call shifts with one in which shifts were never longer than 16 hours and weekly hours were reduced from over 80 to approximately 65. The new schedule resulted in a reduction in medical errors of approximately 30 per cent (Landrigan et al., 2004). A parallel study by the same research group also found that the new schedule more than halved the risk of the doctors being involved in motor vehicle crashes (Barger et al., 2005), presumably because fewer of them drove while extremely sleepy. A study of doctors in the United Kingdom, in which shift length was reduced from 12.5 to 9-11 hours and the total number of weekly hours was reduced from 56 to 48, also produced a significant (33%) reduction in medical errors (Cappuccio et al., 2009).

Gender

Van der Hulst (2003) noted that a large proportion of the studies she reviewed involved all-male samples and that there was a lack of evidence from mixed-gender or all-female samples. More recently researchers have attempted to fill this knowledge gap, although the emerging picture remains somewhat unclear. A Spanish survey of male and female employees in a wide variety of occupations found that among those working more than 40 hours per week, only women were more likely to report increased visits to a medical professional (Artazcoz et al., 2004). However, two subsequent studies by the same authors produced mixed results. They reported findings based on two similar surveys conducted four years apart, in which the associations between long working hours and poor health were stronger among women in the first study, but stronger among men in the second (Artazcoz et al., 2007; Artazcoz et al., 2009). In a recent large-scale survey conducted in the Republic of Korea, there were no significant effects of working up to 59 hours per week on self-reported stress, but working at least 60 hours per week was observed to have an effect, but among men (Park, Yi and Kim, 2010). Gender comparisons of this sort tend to be contaminated by a wide range of other factors such as occupation, job and working time control, engagement in domestic and caring duties, social class and marital status. This makes it is impossible to know whether gender differences in the impact of long working hours are due to the fact that men and women tend to work in different occupations, have different levels of job control, etc. Moreover, cultural differences mean that the relative impact of such contaminating variables may vary between countries.

In cases where women do suffer more problems as a result of working longer hours, it is often suggested that this may be due to the so-called double burden of combining paid employment with unpaid domestic work (e.g. Åkerstedt and Kecklund, 2005). For example, a recent Swedish study based on national survey data found greater levels of self-reported poor health and fatigue (but not anxiety) among women who combined having children with working more than 40 hours a week, compared to childless women (Floderus et al., 2009). The risk increased with the number of children that the respondent had.

There is only one study known to the authors that has examined injury risk in relation to long weekly hours using gender-disaggregated data. Wirtz et al. (in preparation) analyse data from a large-scale survey of a representative sample of the United States population. After controlling for a broad range of potential contaminating factors, including occupational factors, they found that long working hours were associated with a stronger risk of injury in women than in men. The reasons for the difference were not clear. However, in the light of the previous discussion of the double burden, one possible explanation is that it may be linked to differences in levels of fatigue.

Conclusion

What constitutes a healthy and safe maximum for weekly working hours is a vexed issue. Among full-time employees (i.e. working 40 hours or more per week), both sleep problems and risk increase in roughly linear fashion with the number of hours worked per week (Dembe et al., 2005; Virtanen et al., 2009a). In view of the evidence, it is recommended that workers should not work more than 48 hours in any single week.

2.2.2 Short weeks (<30h per week)

Short work weeks appear to be becoming more commonplace, for various reasons, including demographic changes and economic pressures. For example, Jacobs and Gerson (1998) estimated that between 1970 and 1997 the proportion of people working 30 hours or less per week in the United States increased from about 5 to 10 per cent in men and from about 15 to 20 per cent in women. Short work weeks, or part-time jobs, are widespread today, having grown in number after World War II to accommodate employers' needs to cut labour costs and demographic shifts as more women entered the labour force (Tilly, 1996).

Short work weeks are commonly associated with job sharing, where two people share a job, and with reduced load, or customized working time arrangements, where an individual's workload is reduced in return for less pay or hours. Health benefits and pensions may not be not offered with these arrangements unless employees work a minimum number of hours, usually at least 50 per cent or 75 per cent of full-time hours, and even then they may be pro-rated. In some cases, workers negotiate part-time work as a means of retaining their jobs, while in others, employees who would prefer full-time work take these jobs as a way to enter the labour force (Tilly, 1996). In the European Union, the percentage of workers who are part-time employees ranges from 2.3 per cent in Bulgaria to 48.3 per cent in the Netherlands, with an average of 18.8 per cent (Sandor, 2011).

Despite their increased prevalence, there have been almost no studies of the potential impact of short work weeks on health and safety outcomes. Indeed, what evidence there is has to be gleaned from broader studies of working hours that sometimes fail to differentiate between the effects of short working hours and other factors. These other factors include temporary contracts, which are more common among part-time workers and have been found to be associated with an increased risk of fatal occupational injuries (e.g. Villanuava and Garcia, 2011). These authors suggest that this may reflect the fact that temporary workers usually have less experience and training, and worse working conditions. Other contaminating factors include age (many retired workers take part-time jobs), ill-health and gender differences that may themselves be associated with different domestic responsibilities.

Jansen et al. (2003) reported an interesting study of various work schedule features in which they assessed the "need for recovery" using a standardized questionnaire. As might be expected, among the women in their study those working 25 hours per week or less reported significantly less need for recovery than those working 36 to 40 hours per week, and this was true even after the authors had taken into account other variables that could potentially influence the need for recovery, i.e. age, long-term disease, physical demands, emotional demands, psychological job demands and decision-making latitude. In contrast, men working 25 hours per week or less reported a *greater* need for recovery than those working 36 to 40 hours per week, although because of the small sample size this was only significant once the impact of other factors that could contaminate the comparison had been taken into account. The cause of this gender difference appeared to stem from the underlying reasons for working fewer hours. Thus, the small number of men working 25 hours per week or less had a substantially higher tendency to have a long-term disease than those working longer hours, whereas among the women the presence of a long-term disease was not significantly related to their specific working hours.

With respect to occupational injuries, a number of authors have examined the cumulative incidence (i.e. the number of injuries/number of persons) of occupational injuries stratified by working hour categories (e.g. Dembe et al., 2005; Lombardi et al., 2010). As noted elsewhere in this paper, these studies have typically been primarily concerned with long work weeks, where the cumulative incidence is typically higher. However, Lombardi et al. (2010) also reported the adjusted odds ratios (aOR) for those working 20 hours per week or less and 21 to 30 hours per week relative to those working 31 to 40 hours per week. Perhaps not surprisingly, those with the shortest weekly working hours (20 hours per week or less) had a lower incidence (aOR= 0.65) of occupational injuries than those with “normal” working hours (21-40 hours per week). However, those working 21 to 30 hours per week had an elevated incidence (aOR=1.37). The reasons for these results are unclear, but there may be a complex pattern of reasons for different lengths of work week.

Perhaps more importantly, there appears to be no published study that has examined the incidence density of occupational injuries across working hours, i.e. the injury rate per working hour as a function of weekly working hours. As Lombardi (pers. com.) has pointed out, in order to examine this accurately we would need to know the actual number of hours worked each week over the period of the study, and not simply a “one-off” estimate of, for example, the hours worked last week. Nevertheless, if the Lombardi et al. data are crudely corrected for the average hours worked at each level of weekly working hours, the result is an approximation to the incidence density. The results suggest that the hourly rate of injuries is approximately 120 per cent higher among those working 20 hours per week or less, and 75 per cent higher in those working 21 to 30 hours per week, relative to those working 31 to 40 hours per week. Indeed, the hourly rate was then approximately constant over longer work weeks.

A very similar pattern of results was reported in a paper by the United Kingdom's Health and Safety Executive (2000), which concludes that “workers on a low number of weekly hours have substantially higher rates of all workplace and reportable injury than those working longer hours, and the rate gets lower as the number of weekly hours increases”, and that “the relatively high risk in workers with low hours remains after allowing for occupations and other job characteristics”. It would therefore appear that workers on short work weeks have a substantially increased hourly risk of incurring an occupational injury, although the reasons for this are unclear. As Lombardi (pers. com.) has pointed out, in all probability the increased hourly risk associated with short work weeks may be confounded with a number of factors such as riskier jobs, older (retired) workers, younger (student) workers, working mothers, etc. Nevertheless, given their increasing prevalence, there is clearly an urgent need for further research on the potential health and safety implications of short work weeks.

3. Working time arrangements and occupational health and safety

3.1 Work schedules

A large number of studies have examined the impact of various work schedules on health. Recently reviewed in detail by Costa et al. (2010) and C.S. Smith et al. (2011), these studies have typically been found to indicate that shiftworkers whose schedules include night work show a generally higher prevalence of digestive disorders (from 2 to 5 times higher on average) than those whose schedules do not include night work (Costa, 1996; Knutsson, 2003; C.S. Smith et al., 2011). In addition, a number of epidemiological studies have yielded data suggesting an association between shift work and cardiovascular diseases. More specifically, it has been shown that: (i) cardiovascular risk factors, angina pectoris and high blood pressure are prevalent among shiftworkers; (ii) morbidity due to cardiocirculatory and ischaemic heart diseases rises with age and years in shift work; and (iii) there is an increased relative risk of myocardial infarction in occupations with a high proportion of shiftworkers (Knutsson, 2003; Kristensen, 1989). However, a recent review has suggested that the evidence of a causal association between shift work and cardiovascular disease may not be as strong as previously thought (Frost, Kolstad and Bonde, 2009). There is also some evidence for other physical health problems such as cancer (Knutsson, 2003; Schernhammer et al., 2006), increased minor infections (C.S. Smith, Folkard and Fuller, 2003), and maternity problems in women (Knutsson, 2003). There is mixed evidence regarding the association between shift work and musculoskeletal disorders. Only a limited range of shift patterns have been studied in this regard, and researchers have not always controlled for potential confounding factors such as physical job demands (Caruso and Waters, 2008; Zhao, Bogossian and Turner, 2010).

As discussed in Section 1, the health effects of work schedules are chronic in nature and may take many years to manifest themselves. For this reason, it is normally impossible to pinpoint the particular feature of a work schedule that causes them, although in some cases it would appear that work schedules that do not involve night work may be less harmful than those that do. In order to examine the impact of other features of work schedules, more acute measures are usually needed, such as fatigue, injuries and accidents. Work schedules may vary widely from several points of view, including whether the shifts rotate or not, the direction and speed of the shift rotation, the number of consecutive shifts, the length of shifts, the start and end times of each shift, and the number and placement of days off. There are an almost infinite number of different shift systems in operation and none of them is anything like perfect! The systems can nevertheless be classified according to their features, and these features examined by comparing within and between groups of individuals working on different systems.

Rotating versus permanent shifts

A fundamental question is whether workers should regularly “rotate” between different shifts (e.g. between day and night shifts) or whether they should always work the same shift (“fixed” or “permanent” shifts). The basic question is whether permanent night workers can adjust the timing of their body clock such that they can easily sleep during the day and remain alert throughout the night. A recent review of the available evidence concluded “that less than one in four permanent night workers evidence sufficiently 'substantial' adjustment to derive any benefit from it” and that this was equally true for men and women (Folkard, 2008, p. 215). Circadian adaptation to a nocturnal routine by rotating workers on the night shift probably occurs very slowly, if at all. Indeed, epidemiological studies of accident and injury risk indicate that risk increases over at least four successive night shifts, and at a markedly higher rate than is observed over successive day shifts (Folkard and Tucker, 2003). A key factor working against adaption to a nocturnal routine is that workers tend to revert to a diurnal routine on their days off, counteracting the process of circadian adaptation and resulting in their having to start adapting all over again after even just a few days off.

A recent epidemiological study suggests that there may be important gender differences in this respect (Wong, McLeod and Demers, 2010). The overall results of this study indicated that, relative to dayworkers, rotating shiftworkers had a 48.4 per cent higher risk of incurring a compensated work injury while permanent nightworkers had a 91.3 per cent increased risk. However, the gender disaggregated data indicated that there was a large difference between rotating shift work and permanent night work in men (14.5 versus 91.5 per cent increased risk), but virtually none in women (129.0 versus 104.3 per cent increased risk), perhaps reflecting greater domestic and family duties. The results of this study therefore clearly suggest that the advantages of rotating shift systems over permanent ones may be limited to men.

In summary, the available evidence indicates that, at least for men, fixed or permanent night shifts should be avoided in most circumstances. A possible exception is situations where a nocturnal routine may be maintained on rest days (e.g. remote work sites where workers have limited exposure to daylight; Bjorvatn et al., 2006).

Speed of rotation

Speed of rotation refers to the number of shifts of one type (e.g. night shifts) that are worked before the worker either changes to another type of shift (e.g. day shifts) or has a day off. Most research findings tend to favour very rapidly rotating shift systems (i.e. ones that involve working 1 to 3 consecutive shifts of the same type) over more slowly rotating ones (Sallinen and Kecklund, 2010). It has been argued that workers on a more slowly rotating shift system will rarely adjust sufficiently to derive any benefit from it. Instead, they are likely to experience substantial circadian disruption, such that their circadian rhythms remain in a state that is neither fully diurnal nor nocturnal, and hence suffer disturbed sleep between shifts. Permanent night shifts can be viewed as a special case of a slowly rotating shift system (i.e. where the speed of rotation is effectively zero). Thus, it seems that shift systems should seek to minimize the number of night shifts that are worked consecutively (i.e. no more than three consecutive night shifts, but preferably fewer).

Direction of rotation

On rotating shift systems, changing from one type of shift to another entails altering the timing of sleep and most other aspects of daily activity (e.g. meal times, leisure activities). An individual who switches from morning shifts (e.g. 6 a.m. to 2 p.m.) to afternoon shifts (e.g. 2 p.m. to 10 p.m.) will probably go to bed and wake later in the day after the switch, while an individual who switches from afternoon to morning shifts will probably go to bed and wake up earlier after the switch. Most people tend to find it easier to delay sleep and waking than to advance the timing of their sleep, and this is thought to reflect on the natural tendency of the body clock to have a cycle slightly longer than 24 hours (Aschoff and Wever, 1962).

Thus, from a circadian perspective, "forward rotating" shift systems that involve delaying the timing of one's rhythms have been argued to be preferable to "backward rotating" ones that involve advancing the timing of circadian rhythms. However, the evidence is equivocal with regard to the effects on sleep and fatigue (Sallinen and Kecklund, 2010). Although two recent Finnish studies reported improvements in sleep following a change from slowly backward rotating systems to a very rapidly forward rotating system (Harma et al., 2006; Viitasalo et al., 2008), it is unclear whether it was the speed or the direction of rotation that was primarily responsible for the improvements. Moreover, very rapidly backward rotating systems are more likely to feature "quick returns" (short intervals between the end of one shift and the start of the next – see below), which may have a greater impact on fatigue than the direction of rotation *per se* (Tucker et al., 2000). In short, it seems that very rapidly forward rotating shift systems are to be preferred to slowly backward rotating ones, particularly when the latter involve quick returns.

Shift start and end times

Several studies have shown that people working on early morning shifts (e.g. starting before 7 a.m.) tend to have shorter sleeps the night before the shift and are sleepier during the shift (Sallinen and Kecklund, 2010), apparently because they fail to compensate for an early start by going to bed sufficiently early the night before (Folkard and Barton, 1993). This is thought to reflect, at least in part, the influence of the circadian rhythm on sleep propensity, which reaches its lowest point, "the forbidden zone" (Lavie, 1991), in the early evening (at around 8-10 p.m.) before rising steadily to peak in the early hours of the morning (4-6 a.m.). Workers may therefore find it impossible to fall asleep sufficiently early in the evening to compensate for an early start the next day.

At first sight, it might seem appropriate to delay the start of morning shifts so as to reduce fatigue on that shift. However, if the morning-shift workers are replacing a team of night-shift workers, a substantial delay in the change-over time may cause sleep problems for the night-shift workers. Just as morning-shift workers experience difficulty falling asleep in the early evening, so do night-shift workers experience greater sleep problems when they go to bed in the relatively "late" morning, after returning home from the night shift (Rosa et al, 1996; Tucker et al., 1998a). Sleep propensity falls rapidly from its peak between 4 and 6 a.m. until about 1 p.m., implying that the later nightworkers go to bed following a night shift, the more difficulty they may have in falling asleep. They may also find it difficult to stay asleep long enough to recover adequately.

In the light of the trade-off between the sleep needs of those on the morning and night shifts, a shift change-over time of 7 a.m. has been proposed as an appropriate compromise (Åkerstedt, 2003). However, even then workers on both shifts may experience impoverished sleep, particularly if they have long commutes. In situations where the night shift hands over directly to the morning shift, it is recommended that early morning shifts should be limited to three in a row in order to minimize the accumulation of fatigue. If the morning shift does not take over directly from the night shift, then early morning shifts should be avoided completely.

So far the discussion has focused on the way in which shift system design can be used to mitigate the effects of circadian disruption on fatigue, particularly when night work is involved. However, fatigue can also be caused by non-circadian aspects of schedule design such as excessively long working hours (see discussion of compressed work weeks in Section 2.1) or when there is insufficient opportunity to rest and recover during and between shifts.

Distribution of rest days

The key to minimizing the accumulation of excessive fatigue and other problems is the provision of adequate opportunities for rest and recovery, both during shifts (i.e. see *Rest breaks*, below), between successive shifts (see *Quick returns*, below) and between blocks of shifts (i.e. rest days). Weekends provide an important opportunity to rest and recover from the demands of working (Fritz and

Sonnentag, 2005), but there is relatively little evidence regarding the optimum distribution of rest days within rotating shift schedules. One study found that a 12-hour shift system involving 2 days on, 2 days off, resulted in slightly higher alertness than one involving 4 days on, 4 days off (Tucker et al., 1999). Another study (Totterdell et al., 1995) showed that alertness and performance were impaired on the first three days back at work following a single rest day as compared to a span of two or three rest days. Likewise, after reviewing the literature, Åkerstedt et al. (2000) concluded that a single day of rest is never sufficient, that two usually are and that three or four are needed after periods of severely disturbed circadian rhythmicity (e.g. after working several night shifts). More generally, it seems probable that it is the ratio of work days to rest days that is important in enabling full recovery from a period of work, and that under normal circumstances it may be appropriate "to limit spans of successive work days to not more than six and to require a minimum of two successive rest days" (Spencer, Robertson and Folkard, 2006, p. 40).

Quick returns

Quick returns, i.e. short intervals between the end of one shift and the start of the next, often occur in backward rotating shift systems (see *Direction of rotation* above) and are also common when the overall weekly working hours are high (see 2.2 above). They restrict the opportunity for sleeping and other non-work activities between shifts and are associated with shorter sleeps (Axelsson et al., 2004; Kurumatani et al., 1994) and increased fatigue on the subsequent shift (Tucker et al., 2010; Tucker et al., 2000). The impact of quick returns on fatigue is likely to be exacerbated by long commuting times and other factors such as family responsibilities (Kogi, 1982), but there is no clear evidence of their effect on injury risk (see Macdonald et al., 1997; Spencer et al., 2006).

It should be noted that quick returns are a means of compressing the work week, giving longer periods of rest between spans of work days (e.g. Barton et al., 1994). For this reason, quick returns and the shift systems that feature them (some backward rotating shift systems) are often popular with the workforce, but given their impact on sleep and recovery they are best avoided. In fact, the European Working Time Directive requires that workers be allowed a minimum rest interval of 11 hours between successive duty periods.

Rest breaks

Rest breaks during a period of work are a fundamental aspect of any work schedule and several studies have examined their role in preventing musculoskeletal problems, although systematic reviews suggest that there is only limited evidence of their effectiveness in this regard (Brewer et al., 2006; Kennedy et al., 2009). The earlier review also noted that there was insufficient evidence to conclude that rest breaks were an effective countermeasure to eyestrain.

Insufficient rest breaks during the day can be associated with increased work-related stress (D.R. Smith et al., 2009). Evidence has recently emerged indicating that the beneficial effects of rest breaks on strain and mood are influenced by the nature of the activity undertaken during the breaks. An experimental field study demonstrated the effectiveness of incorporating progressive muscle relaxation sessions into lunch breaks in reducing job strain (Krajewski, Wieland and Sauerland, 2010). Another field study found that rest breaks were more likely to enhance subsequent mood if they involved respite activities (e.g. napping, relaxing and socializing) rather than chores (e.g. working with customers, running errands and work preparation; Trougakos et al., 2008).

A very few studies have examined the impact of rest breaks during a shift on injury or accident risk (Tucker, Folkard and Macdonald, 2003; Tucker et al., 2006). They agree that risk is reduced in the first half hour following a rest break, and that this effect is similar across all three shifts. The trends over subsequent half hours varied, possibly reflecting the extent to which the work was either self-paced or machine-paced. It would therefore appear that the beneficial effects of rest breaks may be relatively short-lived in at least some work environments. Relatively few studies have provided evidence regarding the optimum timing and duration of rest breaks, and most of these have focused on outcomes such as performance, physiological indices of strain, or subjective indices of fatigue and comfort. Their results suggest that frequent short breaks are beneficial and that fatigue management is improved when the timing of rest is at the discretion of the individual, although this is clearly not feasible in many situations. There is conflicting evidence regarding the optimum duration of rest breaks, and it seems likely that both the optimum scheduling of rest breaks and their likely beneficial effects will be affected by the nature of the work (Tucker, 2003). Thus, while there is a clear need for more research on the optimum scheduling of rest breaks, the limited available evidence suggests that schedules should aim to incorporate frequent short breaks (e.g. 15 minutes every two hours), rather than fewer longer ones.

Split shifts

Split shifts involve working more than one duty period in a "working day". They have the potential to have a negative impact on both fatigue and well-being, although there appears to be relatively little published empirical research on their effects. They may affect fatigue if they are arranged in such a way as to restrict rest opportunities between duties. Night-time recovery may be limited if, for example, the schedule features both early morning starts and late finishes (see *Shift start and end times* above). Recovery during the daytime between duties may also be limited if, for example, there are no appropriate rest facilities at or near the workplace for workers who are unable to go home between duty periods. Even if the workers are able to access appropriate rest facilities during the day, they may have limited time to rest between duty periods and may be unable to sleep well owing to circadian influences.

Split shifts are common in passenger transport environments, where schedules are designed to meet the peak demand associated with morning and evening rush hours. In the investigation of a commuter train accident in the United States, it was suggested that one of the causal factors was inadequate night-time rest associated with split shifts (Sussman and Coplen, 2000). However, a large-scale survey examining the association between shift schedule features and the risk of job-related injuries in a broad range of occupational settings failed to find that split shifts had an effect (Dembe et al., 2006). Comparing these two reports suggests that while split shifts may not be inherently riskier *per se*, they may be associated with increased risk if rest and recovery between duty periods is impeded.

Split shifts are also found in various forms of precarious employment, in sectors such as retailing, hospitality and catering. In these situations, they often coincide with other problematic work schedule features, such as irregular and unpredictable hours of work. Split shifts are therefore often seen as contributing to the stress experienced by workers who have difficulty managing their work and life responsibilities, and who may also experience fluctuations in income (Bohle et al., 2004; Zeytinoglu et al., 2004). Thus, as with safety risk, split shifts may not be inherently more stressful *per se*, but they may be commonly associated with other work schedule features that are.

Combined effects of shift work and other occupational hazards

Both long shifts and unusually timed shifts may heighten the impact of other occupational hazards. As Knauth (2007) noted, little is known about the relationships between extended shifts and the effects of exposure to toxic or other environmental hazards such as hazardous materials, radiation, biological agents, extreme temperatures, vibration or noise. The shorter intervals between extended shifts (e.g. 12-hour intervals between 12-hour shifts, as opposed to 16-hour intervals between 8-hour shifts) mean that there is less time for toxic clearance between shifts. Chemicals that are not quickly eliminated from the body may consequently accumulate. Knauth cited a German study that used mathematical models to examine the effects of prolonged daily and weekly exposure to toxic substances (Jung et al., 1998). It concluded that the toxicity of substances with medium half-lives (10-1000 h) is increased in extended shifts (i.e. 10 or 12 hours), resulting in a quicker accumulation of toxins in the blood compared to 8-hour shifts. Knauth also cited a study of 8-hour shiftworkers exposed to high levels of workplace chemicals in which additive effects of exposure were identified (Kiesswetter et al., 2000). The researchers concluded that longer shifts and compressed working hours could not be recommended under such circumstances.

This problem of combined effects may be even greater in the case of abnormally timed, as opposed to simply extended, shifts. This is because there are pronounced circadian rhythms in the metabolism and excretion of toxic substances. For example, a fixed dose of cyanide (77.5mg/kg) kills 100 per cent of mice (standardized to a 24-hour light (6a.m.-6 p.m.) / dark (6 p.m.-6 a.m.) cycle] at 8 p.m. but only 30 per cent at 8 a.m. (Bafitis et al., 1978). Likewise, the cutaneous response of people allergic to histamine and house dust shows a pronounced circadian rhythm, bottoming out at about 7 a.m. and peaking 12 hours later at about 7 p.m. (McGovern, Smolensky and Reinberg, 1977). Clearly, risk assessment and biological monitoring should take account of potential circadian fluctuations in absorption, metabolism and excretion, and the consequent severity of the toxic effect. Safe Working Limits (SWLs) and Biological Exposure Indices (BEIs) need to take account of both the duration and timing of shifts. Indeed, some studies have already shown a circadian excretion pattern of toxic substances or metabolites that can be used to improve workers' bio-monitoring (Goyal et al., 1992; Smolensky, Paustenbach and Scheving, 1985).

In short, it would appear that safe working limits for chemicals, hazardous materials and other occupational hazards, which have been determined on the basis of "normally timed" 8-hour shifts, should be reconsidered and recalibrated to take account of the timing and duration of shifts.

Young workers and cultural differences

There is a considerable literature on a wide range of demographic differences in fatigue and the risk of driving accidents (reviewed by Di Milia et al., 2010), but limited research on the impact of shift work on youths and adolescents. What evidence there is suggests that special consideration should be given to the needs of young workers with regard to their working time arrangements. Loudoun and Allan (2008) note that adolescents tend to face adverse working conditions in relatively poor quality jobs, resulting in a higher risk of injury compared with adults. Moreover, they are often employed in the service sector, where evening and night work are common. However, little research has focused on the specific impact of adolescents' working hours. The disruption of internal timing mechanisms experienced by all shiftworkers may be especially problematic for teenagers because of their accelerated growth during puberty, which results in their having phase-delayed circadian sleep-wake rhythms and a higher need for sleep (Wolfson and Carskadon, 1998).

Loudoun and Allan reported that adolescents in Queensland, Australia, were substantially more likely to suffer injuries than adults. The risk for adolescents was greater on both day and night shifts, but more so at night, with youths being 3 to 5 times more likely to sustain injury than their adult counterparts. One reason put forward was that adolescents were more heavily concentrated in industries such as food retailing and café and restaurant work, where injuries associated with preparation and cooking are common. It was also noted that many night-working youths are effectively working double shifts, going to school and engaging in other social activities during the day on top of paid work at night (see also Fischer, Nagai and Teixeira, 2008). In terms of health, adolescents tend to need more sleep and so sleep deprivation (e.g. due to work schedule demands) may have especially negative effects on their well-being. Oginska and Pokorski (2006) reported on a study of adolescents and young adults in which the adolescents indicated the greatest sleep need. They found that insufficient sleep had more negative consequences in younger than in older participants.

The authors are aware of few studies that have featured cross-cultural comparisons of the health and safety effects of shift work or its effects on migrant workers. They would argue that while shiftworkers in developing countries face many of the same challenges as their counterparts in developed countries, these difficulties may well be exacerbated by the generally poorer working and living conditions in those countries. Measures for monitoring and protecting shiftworkers' health and safety are therefore even more essential in developing economies, and the benefits of participatory programmes and a democratic work environment may be even more salient. Additional specific measures may also be necessary, such as improved sleeping quarters. Shiftworkers in developing countries experience unfavourable climatic conditions (usually high temperatures) and poor housing conditions, making sleep during the daytime even more problematic than it otherwise would be, with obvious implications for health and safety (Fischer, 2001; see also Tucker, 2006).

Tepas et al. (2004) compared ratings of the well-being of nightworkers and non-nightworkers in the health-care sectors of five different countries (Brazil, Croatia, Poland, Ukraine and the United States). Their findings suggested that the impact of night work on perceptions of well-being differed between countries, with some nationalities reporting a more negative impact on physical tiredness than others. Possible reasons included differences in working time regulation and the amount of public and social support offered to nightworkers. Barnes-Farrell et al. (2008) also made an international comparison of shiftworkers in the health-care sector from Australia, Brazil, Croatia and the United States, but found no national differences in the impact of shift characteristics on self-report measures of work-family conflict, physical well-being and mental well-being. However, their analyses controlled for cultural factors such as work demands, family demands and personal characteristics – suggesting that any national differences that did exist may have been due to national differences in these variables.

In summary, it is hard to draw any firm conclusions on national differences in the effects of shift work on the basis of such limited evidence. However, it seems likely that where such differences do exist, the underlying causes will be complex and multi-factorial.

3.2 Flexible working time arrangements

Flexible working hours (FWH) are those in which the employee's hours of work may vary, either from one duty period to the next, from week to week or across the year. They are commonly characterized by variations in the start and finish time of individual duty periods and/or in the days that are worked (and, in the case of shift work, the shifts that are worked). Variations in working time may be primarily either under the control of the employer or at the discretion of the individual employee. These two forms of flexibility have been termed "variability" and "flexibility" (Costa, 2006), in an effort to distinguish between the different effects that are associated with each. Research has tended to find that while the former is associated with negative impacts on health and well-being, the latter most often results in positive outcomes.

It is important to note that while many studies have tended to focus on one or the other form of flexibility, the two are not mutually exclusive. Thus, in practice, the majority of studies can be said to have examined situations in which one form of flexibility *predominates* over the other. It is theoretically possible to have a FWH arrangement in which the two forms of flexibility co-exist in more or less equal measure. In such instances, the hours worked by an individual are often determined by a system which attempts to match the requirements of employer and employee (e.g. annualized hour systems; Tucker, Gaertner and Mason, 2001). However, no empirical studies that we are aware of have examined the impact of such systems. In any case, it seems likely that the relative merits and demerits of any such system will be determined by how successfully it balances the two party's needs in practice.

Methodological issues

Early studies of flexibility were sometimes less than explicit in differentiating between the two types of flexibility, resulting in some apparent inconsistencies between findings. The waters were further muddied by some researchers using relatively broad definitions of FWH, for example by including compressed work weeks, part-time work and even shift work under the general heading. The effects associated with the last two working time arrangements often differ markedly from one another and from those of "traditional" flexibility (as defined at the start of this section), resulting in further apparent inconsistencies. Another problem with such broad definitions is that such working time arrangements do not necessarily feature variation in working hours. It is perfectly possible for schedules such as compressed work weeks to involve working the same (non-standard) hours every week throughout the year. These other forms of non-standard working time arrangements are discussed elsewhere in this report, so the current discussion will adopt the relatively narrow but clearly focused definition of FWH proposed by Costa et al. (2004, p. 835): "Flexible Working Hours should involve a continuous choice on behalf of employers, employees, or both, regarding the amount (chronometry) and temporal distribution (chronology) of working hours."

FWH are one of a number of flexible working arrangements which, in practice, may operate alongside one another. For example, so-called teleworkers have flexibility of working location, spending some or all of their time working away from their employer's premises (e.g. at home). Teleworkers may also be more likely to work outside the normal operating hours of their employer's premises (Golden, 2001), for example, checking and responding to emails in the evenings and at weekends. The potential for FWH to co-exist alongside other flexible working arrangements highlights the possibility of other factors contaminating comparisons between FWH and situations in which employees have inflexible working hours.

Another potential source of inconsistency in the reported effects of employee-led FWH is the way in which different researchers have operationalized the term "flexibility". Some studies have measured *perceived* flexibility, or flexibility as a job characteristic. However, others have focused on the effects of company policies that are intended to promote flexibility, even though those policies may not enhance flexibility in practice (Kossek and Michel, 2010). It is also important to distinguish between the availability of flexibility and its actual use (see, for example, L. Smith, Hammond et al., 1998).

"Flexibility", i.e. employee-led FWH

There are many potential forms of flexibility, even within the relatively narrow definition proposed by Costa et al. Examples include: being able to swap shifts or duty periods with workmates; being able to request in advance which days or shifts are to be worked ("period-planned work hours"; Eriksen and Kecklund, 2007); flexible daily hours, featuring self-determined start and finish times around a set of core hours ("flexitime"); and "trust hours", when employees are given a high degree of time-autonomy to achieve their work-related goals (i.e. their performance is judged on the basis of output rather than input).

There do not appear to have been any studies that have systematically compared the effects of these different types of flexibility. Part of the difficulty in undertaking such a comparison is that the relative merits of each are likely to depend on the type of work involved. The different forms of flexibility tend to be associated with different occupations and positions of seniority. For example, flexitime is most common among professional and higher-level employees. It is less suited to manufacturing industries (e.g. assembly-line work), where completion of work tasks requires interdependence between workers (Baltes et al., 1999). Conversely, flexibility in terms of which days or shifts are worked are better suited to manufacturing settings, if the start and finish times remain invariant.

Baltes et al. (1999) conducted a meta-analysis of studies of flexitime (and compressed work weeks) that focused on "work-related" outcomes (i.e. productivity, satisfaction and absenteeism). They found that flexitime had strong favourable effects on absenteeism, as well as rather less strong but also favourable effects on productivity, job satisfaction and satisfaction with schedule (but not self-rated performance). Managers and professionals tended to benefit less from the implementation of formal flexitime arrangements than other employees, perhaps because the former have less to gain as their jobs are inherently more flexible (i.e. they already enjoy a relatively high degree of flexibility prior to implementation). They also found that schedules with relatively long "core hours" (i.e. less flexibility) were associated with more positive performance outcomes than schedules with shorter core hours. This unexpected finding was attributed to more flexible schedules causing more problems of coordination between colleagues. They also found that the effectiveness of implementation tended to decrease over time, suggesting that employees become accustomed to the new arrangements and come to view them as the norm.

Baltes et al. suggested that improvements in productivity and performance may derive from enhanced person-job fit (e.g. by allowing employees to match their work hours to their circadian rhythms) and enhanced job autonomy (after Hackman and Oldham, 1976). They also suggested that the latter may underlie some of the improvements in job satisfaction. The improvements in absenteeism were ascribed to reduced work-life conflict, as well as to enhanced job satisfaction and organizational loyalty. Flexibility is particularly attractive to employees if they have extra-work commitments, such as family or other caring duties. Hence employees who report greater schedule flexibility and increased control of working time tend to experience less work-family conflict (see reviews by Byron, 2005; Eby et al., 2005). It seems likely that some of the improvements in productivity identified by Baltes et al. may derive from improved satisfaction and motivation resulting from enhanced work-life balance (Greenhaus and Powell, 2006). Employers who offer their staff flexibility are also more likely to be able to attract staff, reduce turnover and enjoy associated cost savings (Kossek and Michel, 2010).

It is likely that the positive effects of flexibility on the employee’s experience of work itself, as well on work-family conflict, underlie associations between flexibility and positive health and well-being outcomes. Perceived schedule flexibility has been associated with better self-reported cholesterol

(Thomas and Ganster, 1995), fewer symptoms of physical ill-health, better psychological well-being (Ala-Mursula et al., 2004; Grzywacz, Carlson and Shulkin, 2008; Jansen and Nachreiner, 2004), fewer absences due to sickness (Ala-Mursula et al., 2004) and lower risk of early retirement due to musculoskeletal disorders (Vahtera et al., 2010). A number of shift work studies have demonstrated the positive effects of control over shifts on self-reported health (Barton et al., 1993), blood pressure (Viitasalo et al., 2008) and psychological health (L. Smith, Hammond et al., 1998). Working time control has also been shown to ameliorate the negative impacts of various work-related stress factors (including long working hours) on absence due to sickness (Ala-Mursula et al., 2006; Ala-Mursula et al., 2005). A recent systematic review of flexible work scheduling concluded that arrangements which give workers some control over their scheduling tend to result in at least some improvements in health and well-being (Joyce et al., 2010). It also concluded, however, that there was insufficient robust evidence from methodologically sound studies to draw firm conclusions regarding the existence of such a causal relationship.

A number of researchers report that women are most likely to report benefits of flexibility, for example in terms of work-family conflict (Byron, 2005), stress and burn-out (a syndrome characterized by psychological exhaustion and disinterest, associated with work-stress; Grzywacz et al., 2008), self-reported health issues, psychological distress and sick leave (Ala-Mursula et al., 2004). This probably reflects the tendency for women to be more engaged in domestic duties (e.g. child care) than men. Employees with children (especially women) are most likely to report that work-family conflict is reduced by flexibility (Ala-Mursula et al., 2004; Byron, 2005; Jansen et al., 2004). Moreover, the positive impact of perceived flexibility is greatest among workers whose spouses are in full-time employment (Grzywacz et al., 2008), which probably also reflects the benefits of flexibility on managing child care. However, flexibility can be seen as a way of putting the onus for child care on the individual (usually women) while absolving the State of responsibility (Joyce et al., 2010), and may therefore have negative consequences for women. For example, women may end up engaging in more non-work responsibilities, rather than using the increased control and time to lower stress and strain outcomes (Hammer et al., 2005). While the effects of flexibility on life outside work may be greater for women than for men, what little evidence there is suggests that there are no such gender differences in the positive impact that flexibility has on productivity and organizational commitment (Eaton, 2003).

The perceived benefits of flexibility will depend on how the individual prefers to manage the boundary between work and non-work. According to Rothbard et al. (2005), flexibility can be viewed as way of allowing employees to maintain the boundary between work and non-work (in contrast to policies such as having child-care facilities at work, which, they argue, promote integration of work and non-work activities). They found that individuals who prefer to maintain such boundaries and avoid integration showed greater organizational commitment if given more access to flexitime. However, under some circumstances flexibility can be associated with the breakdown of work/non-work boundaries. In particular, when workloads are high and there are ambiguous norms about working hours, the employer may exert pressure on the employees to restructure their personal time to work (Kossek and Lee, 2008). In such circumstances, flexible work schedules (along with teleworking) may foster a culture of overwork.

The contrasting possible effects of flexibility, as outlined above, highlight how the benefits of flexibility are highly contingent on management policies and attitudes towards flexibility, even when it is employee-led. For example, it is important that when employees are given the opportunity to vary their work hours, they are not inadvertently punished for doing so, e.g. by being regarded as less committed to the job and hence being overlooked for promotion (T.D. Allen and Russell, 1999; Judiesch and Lynes, 1999; Thompson, Beauvais and Lynes, 1999). The successful implementation of a flexible work schedule policy thus depends on it being supported by informal supervisory practice. If the policy only exists on paper but not in practice, then the benefits associated with increased job autonomy and schedule control will be lost (Kossek and Michel, 2010). Supervisors may not always be inclined to favour flexibility, as it can present them with a number of challenges. For example, flexibility can make communication and coordination with and between employees more difficult, and hence may involve additional managerial planning and implementation costs (Baltes et al., 1999).

There is a risk that individuals allowed to determine their own working hours may impose on themselves work routines that are excessively fatiguing, without adequate rest and recuperation (Eriksen and Kecklund, 2007). They may do this in an effort to compress the work week (so as to achieve longer breaks between work weeks), to increase earnings, or to meet excessively high goals that are either set by supervisors or that are self-imposed; such routines may also result from shift swaps with colleagues. This could, in theory, result in impaired health and/or an increased risk of accidents, although there is relatively little direct evidence of this occurring in practice. Nevertheless, if flexibility is to become more widespread, it is important to remember that individuals differ substantially in their vulnerability to sleep loss and may not be able to self-assess their level of vulnerability. Van Dongen and Belenky (2009) have proposed techniques for testing and predicting an individual’s vulnerability to sleep deprivation and non-standard work schedules.

"Variability", i.e. employer-led flexibility

The previous section made it clear that giving employees control over their work hours is broadly associated with positive effects on well-being. A corollary of this is that when control is taken away from the employee and placed in the hands of the employer, employee well-being may suffer. This negative impact is likely to be exacerbated if the imposed working hours change often in a largely unpredictable manner (Costa, 2006; Costa et al., 2004; Costa et al., 2001). Variability has therefore been variously associated with negative effects on subjective health and well-being, psychological well-being and sleep quality and leisure time (Jansen and Nachreiner, 2004; Martens et al., 1999). However, as with flexibility, the effects of variability can vary between individuals. For example, Kandolin et al. (2001) reported that while employer-led flexibility (i.e. requiring employees to work overtime, weekends and nights) was associated with more social disruption and mental stress, the effects were only prevalent among those experiencing high time pressure in their work.

Conclusions

A substantial body of evidence indicates that providing employees with flexibility and control over their working time is associated with positive outcomes in terms of health and well-being, as well as positive organizational outcomes such as increased productivity and reduced absenteeism and turnover. At the same time, it is evident that denying workers schedule control and imposing variability of working hours results in negative health and well-being outcomes. However, despite the substantial weight of available evidence, the mechanisms underlying some of these associations are not yet fully understood. For example, it is not clear what mechanisms underlie the improvements in productivity that are associated with flexibility. While some have suggested that this is linked to improvements in the workplace itself (e.g. the suggestion by Baltes et al. regarding the role of improved person-job fit), others, such as Kossek and Michel, suggest that enhanced motivation and satisfaction deriving from improved work-life balance are key factors. Of course, such explanations are not mutually exclusive.

It is important to note that shift work research has tended, on the whole, to focus on physical health and safety issues, while studies of flexible working have mostly tended to focus on psychosocial effects.

This may reflect the fact that, traditionally, shift work has been more commonly associated with blue-collar jobs, while flexible working has been more commonly associated with white-collar jobs. However, with the advent of the 24-hour society (i.e. the availability of services outside the traditional day-time hours of 9 a.m. to 5 p.m. or even around-the-clock), an increasingly broad set of occupations are set to feature non-standard working hours in the coming years. Moreover, flexible working practices are set to become more widespread, not least due to the adoption of legislation in several countries requiring employers to offer "family-friendly" working time arrangements. Flexible working is also increasingly being seen as a way for employers to attract and retain staff at all levels in occupations where there are skill shortages (e.g. nursing). The future is therefore likely to see a blurring of the associations between occupational groups and their traditional types of working time arrangements. This may also prompt researchers to focus on the psychosocial consequences of shift work, as well as on the health and safety consequences of flexible working.

Many of the studies in this field suffer from methodological weaknesses such as reliance on self-report data, the use of cross-sectional designs and relatively small samples, with obvious implications for the robustness of the findings that result. This point was illustrated in a recently published systematic review of flexible working arrangements (Joyce et al., 2010). Of 200 studies of such arrangements initially identified, only one study of flexitime and four studies of self-scheduling/flexible scheduling of shift work met the inclusion criteria. These criteria required that the studies should feature a robust study design, the use of accurate and reliable health measures and a follow-up period of six months or greater. The authors of the review called for future studies to involve methodologically rigorous designs (e.g. designs which compare groups of workers before and after an intervention alongside matched control groups that do not undergo the intervention), the use of objective measures of health and adequate follow-up periods. They also stressed the importance of making explicit the background and motivation for an intervention, how it was delivered and whether it was supported by workers and managers. Finally, they also highlight the need for analyses by subgroups so as to examine health inequalities. Surprisingly, the review did not mention the recent studies by Ala-Mursula and colleagues (Ala-Mursula et al., 2006; Ala-Mursula et al., 2005; Ala-Mursula et al., 2004), whose designs have addressed a number of the criticisms made of earlier studies.

As noted above, there is little evidence regarding the relative merits of different forms of flexibility, although this is likely to be job-specific. Similarly, there is relatively little evidence regarding the most effective way of balancing flexibility needs between employer and employee, although once again this is likely to be quite situation-specific. What is needed is a set of guiding principles enabling practitioners to advise individual client organizations on the introduction of FWH.

4. Modelling the impact of working hours and working time arrangements

As noted previously, the fact that shift systems can vary in so many ways means that there are vast numbers of potential shift systems. Some of their features are almost inextricably linked, such that a change in one aspect almost inevitably means a change in another (e.g. changing from a backward to a forward rotating shift system typically eliminates quick returns). There are also potential conflicts between some of the recommendations, e.g. the need for morning shifts to start relatively late conflicts with the need for night shifts to finish early. Further, the features may interact with each other, such that the impact of one feature on fatigue (e.g. shift length) depends critically on the value of another feature (e.g. the frequency of rest breaks; Folkard and Lombardi, 2006). Clearly, therefore, all features of a work schedule, and the potential interactions between them, must be taken into account simultaneously, obviously a complex undertaking given the large number of critical features.

This complexity is a major problem for those wishing to design better shift systems. Furthermore, organizational factors often result in potential shift systems having to be evaluated in the absence of any real data. In an attempt to address these difficulties, researchers have developed various mathematical models to predict fatigue levels on any given shift system. The original models were typically based on fatigue data from a broad range of sources, including both laboratory and field studies in which frequent subjective ratings of fatigue had been obtained. They allowed the user to specify a shift system design in terms of a range of parameters (i.e. the features of shift systems) and to obtain estimates of the relative fatigue level. These models were typically based on a theoretical model of the sleep and circadian system and required the timing of prior sleep and waking, or in some cases simply working hours, as the primary input; they produced a time-course of predicted fatigue as their primary output. There are now a number of fatigue models described in the scientific literature that are based on the seminal model proposed by Borbély (1982) for predicting how levels of sleepiness (and hence the likelihood of falling) vary as a function of time of day. Borbély's model comprised two processes: (i) how long the individual had been awake, and (ii) the influence of the body clock (see Section 1). The fatigue models derived from Borbély's work have been used to help organizations make decisions about how they will manage fatigue (see below).

The best known of the models are listed below.

Three-process model of alertness (Åkerstedt, Folkard and Portin, 2004; Mallis et al., 2004) – The three-process model of alertness is an extension of Borbély's model, whereby a third process is added representing the heightened sleepiness that is present for a while after waking (the "wake-up" or "sleep inertia" effect). The model takes as inputs work-rest history or sleep-wake history (from records, self-reports, or estimated from work-rest history). It then estimates sleep and predicts subjective alertness, neurobehavioural performance and fatigue risk. This model has been validated in workplace and shift work settings and has been used as a tool to manage shift work and predict accident risk.

System for aircrew fatigue evaluation (SAFE) (Belyavin and Spencer, 2004; Mallis et al., 2004) – SAFE is a version of Borbely's two-process model, i.e., without a sleep inertia component but with a function that is equivalent to the combination of Borbély's "how long the individual had been awake" and the "wake-up" effect. The SAFE system takes self-reported sleep-wake history as its input and validates it against experimental data to predict subjective alertness and neurobehavioural performance. It is implemented as a freestanding tool for civil aviation and as a component of a larger, integrated system to evaluate human performance under environmental stress.

Interactive neurobehavioural model (Jewett and Kronauer, 1999; Mallis et al., 2004) – The interactive neurobehavioural model is a three-process model involving a combination of elapsed time awake, the circadian rhythm of the body clock, and sleep inertia. It models the circadian rhythm using two interacting Van der Pol oscillators (Kronauer et al., 1982) that are reset with light exposure in accordance with previous research findings (Jewett and Kronauer, 1999). The model takes sleep-wake history (preferably measured objectively by means of a monitoring device worn on the wrist, known as an actigraph) and light exposure as inputs. It predicts neurobehavioural performance and is validated against experimental data. The model aims to enable fatigue management in the operational environment. To our knowledge, it is not presently available commercially.

Sleep, activity, fatigue, and task effectiveness (SAFTE) (Hursh et al., 2004; Mallis et al., 2004) – The SAFTE model is an eclectic three-process model with an additive combination of elapsed time awake, circadian rhythm and sleep inertia. It takes as its input sleep-wake history measured directly by actigraph or self-report, or estimated from shift timing and duration and time of day. It predicts neurobehavioural performance, particularly the psychomotor vigilance task (a simple visual reaction time task; see Dinges and Powell, 1985), and has been validated against laboratory and field studies.

Fatigue Audit InterDyne (FAID) (Mallis et al., 2004; Roach, Fletcher and Dawson, 2004) – The FAID model is loosely based on Borbély's two-process model. It was developed to predict worker fatigue directly from shift schedules. Its sole inputs are start and end of work shift. FAID claims not to predict fatigue *per se,* but rather a "sleep opportunity" or work-related fatigue. The model has been validated against laboratory studies and field studies in industry.

Circadian Alertness Simulator (CAS) (Mallis et al., 2004; Moore-Ede et al., 2004) – CAS is loosely based on Borbély's two-process model and was developed as a tool to assess the risk of diminished alertness in the workplace. It has been validated against work/rest and accident data from the trucking industry.

It should be noted that in most models, sleep prediction algorithms have been added at some stage to allow sleep timing and duration to be predicted from the timing of the work periods.

The leading fatigue risk models were compared in 2002 at the International Fatigue Risk Management Conference in Seattle, sponsored by the United States Departments of Transportation and Defense. In order to compare their predictive validity, the models' authors were given a variety of scenarios to model, and the outputs from the models were then compared with the results obtained in objective studies. In most cases, the models failed to provide an adequate fit to the raw data (Van Dongen, 2004). Indeed one of the meeting's organizers concluded that, "The outputs from the models agreed with one another rather better than they did with the raw data" (David Neri, pers. com.). In other words, there is little to choose between these models and they are of limited predictive validity, although they are clearly better than nothing!

One fundamental problem with these models is that they are essentially theoretical and designed to predict the timing and duration of sleep and hence the subsequent fatigue levels. An alternative, atheoretical, or "weather forecasting", approach is represented by the original Fatigue Index developed by the United Kingdom Health and Safety Executive (HSE) (A.S. Rogers, Spencer and Stone, 1999). This Index included six factors associated with the development of fatigue, namely: the length of the shift, the interval between shifts, the number of rest days, the quality of the rest breaks, the variability of the shifts, and the time of day. Scores were assigned fairly arbitrarily to the possible levels of each factor and then each factor was scored independently and the composite score used to provide an overall index of fatigue. A revised, more sophisticated version that takes account of the potential interaction between some factors was produced in 2006 and is freely available from the HSE website (see Spencer et al., 2006).

Another problem with the fatigue models is that variations in fatigue and the risk of injuries and accidents have been found to show systematic differences (Folkard and Åkerstedt, 2004). Folkard and his colleagues have therefore developed an alternative Risk Index that is based on systematic trends in the risk of injuries and accidents (Folkard and Lombardi, 2004; Folkard et al., 2007). This is again a totally atheoretical index that uses simple mathematical formulae to combine the established trends in risk associated with various features of work schedules. The major advantages of the Risk Index are that it has a high face validity and that the output is expressed as the risk associated with any given work schedule relative to that of a "standard" schedule.

The latest version of the Risk Index has been incorporated into the HSE Fatigue/Risk Index (Spencer et al., 2006). Both indices are constructed from three separate components, namely: "(i) a cumulative component based on the pattern of work leading up to any given shift, (ii) a duty timing component concerned with the effect of start time, shift length and the time of day throughout the shift, and (iii) a job type/breaks component which relates to the activity being undertaken and the provision of breaks during the shift" (Folkard et al., 2007, p. 177). The inclusion of the third component reflects the importance of taking situational factors into account when seeking to optimize shift system design. The user of the model is able to input information regarding the typical workload involved in the job, the degree of continuous attention required and the typical commuting time. However, like the more theoretical fatigue models, this model fails to take account of most known individual differences associated with factors such as age (Harma, 1996), gender (Estryn-Behar et al., 1990) and personality (Kerkhof, 1985).

5. Minimizing the adverse effects of working hours and working time arrangements

As was outlined in Section 3, work schedules clearly have a large number of features that, in combination with one another, will determine the acceptability or otherwise of a given schedule. In many cases, these features will interact with one another such that, for example, the acceptability of a long shift may depend on the frequency of rest breaks within it, its timing within the 24-hour day, and the number of successive shifts before a period of rest days. For this reason, it is extremely difficult to design a set of limitations to ensure that work schedules are acceptable. Indeed, as Folkard and Lombardi (2006) demonstrated, a simple limit on a particular feature of work schedules, such as the maximum permissible number of hours per week, is likely to be of virtually no value in minimizing adverse consequences. To ensure that the adverse consequences are minimized would require placing limits of the sort proposed in Section 2 on all the possible features of working time and work schedules simultaneously. A set of prescriptive limitations of that kind is unlikely, however, to be able to take account of all the potential interactions between the features of work schedules. Thus the limit on any given feature would have to assume that the work schedule was at the extreme limit on all the other features. A set of prescriptive limitations on all features of work schedules would thus almost certainly prove over-restrictive in most situations. This is one of the main reasons why the various models discussed in Section 4 were developed, since they aim to assess the various features of work schedules in combination with one another rather than in isolation.

5.1 Background

Regulations governing traditional hours of work place simple limits on maximum work hours and minimum rest breaks. Historically, regulatory limits on hours of work aimed to balance working conditions and remuneration. In the United Kingdom, the industrial revolution increased the focus on limiting hours of work, particularly in the textile industry. From the late eighteenth century onwards, various movements emerged to advocate limits, the aim being to maintain quality of life (e.g. “8 hours work, 8 hours recreation, 8 hours rest”) and protect women and children in particular. The Factories Act (1802) was the first government regulation limiting working hours in the United Kingdom, but little effort was invested in workplace inspections or enforcement. However, it paved the way for the better known Factory Act of 1833, which restricted the duration and timing of work, especially for children, and provided for lunch breaks and for workplace inspections in the textile industry (Cornish and Clark, 1989).

These movements had parallels in other countries, including the United States, Australia, New Zealand, France and Germany, and they laid the groundwork for the development of regulations to limit working hours across a range of industries. The regulations tried to balance productivity, investment return, wages, quality of life and safety, using the minimal scientific evidence available to inform the choice of safe limits. Not surprisingly, limits were frequently revised. The Hours of Service Act of 1907, which limited the duty time of railway engineers in the United States, was the first regulation to prescribe limits on hours of work for safety reasons (Jones et al., 2005). Since then, governments around the world have imposed a range of legal hours-of-work limits for controlling fatigue and promoting the health and well-being of workers, but these limits have tended to be very simplistic and have typically only considered the maximum number of hours that can be worked per day or per week and the minimum duration of rest periods.

In some countries, the 1970s saw a significant shift away from the traditional focus on prescriptive limits on working hours towards a more general duty of care for managing workplace safety in a more integrated manner, while separating it from considerations of remuneration. In the United Kingdom, the influential Robens Report (Robens, 1972) laid out the principles for the Health and Safety at Work Act (1974), which aimed to reduce industrial and other accidents. Robens argued that the Factory Acts and Regulations were too numerous, elaborate and overly focused on the physical circumstances of work, rather than on workers and safe systems of work. He proposed legislation confined to broad statements setting goals for safety and dealing with environmental standards, particular hazards and particular industries. Rather than prescribing specific limits, regulators take on the responsibility to educate, and to develop non-statutory codes of practice, preferably in consultation with industry and workers' organizations. Following the Health and Safety at Work Act (1974) in the United Kingdom, similar occupational safety and health (OSH) legislation was enacted in Canada, Australia and New Zealand.

Within the general area of working hours and schedules, the principles of duty of care and shared employer/employee obligations for safety and health have been integral to the Fatigue Risk Management Systems (FMRS) primarily developed in the transport sector. In view of the potential risk to members of the general public in this sector, the emphasis has usually been on minimizing fatigue and risk in the operators rather than on their health and well-being. The employers' general duty of care for the safety of employees and others in the workplace is complemented by the duty of employees to report fit for work, behave safely in the workplace, and contribute to safety management. This redistribution of responsibility for safety and health under performance-based OSH legislation has profound implications for the level of personal responsibility of employees and for the legal liability of organizations

The emphasis on safety rather than health and well-being is reflected in the definition recently proposed by Gander et al. (2011), namely that an FRMS "provides a layered system of defences to minimise, as far as is reasonably practicable, the adverse effects of fatigue on workforce alertness and performance, and the safety risk that this represents". Clearly, a full-scale FRMS should be a partnership between management and the workforce that uses safety management systems and processes to continuously monitor and manage fatigue risk.

The development of FRMS within the safety-critical transport industry reflects the development of a particular type of occupational safety and health management system (OSHMS) for situations where there is a high public or environmental risk. In these "high hazard" situations it is understandable that the health and safety of the workforce might sometimes take second place to that of the public or environment. However, it can be argued that in most situations what is needed is a broader, integrated OSHMS approach that manages not only fatigue, but also well-being, health and safety. Such an approach has been developed in detail by the ILO (ILO-OSH, 2001) but we are unaware of any published studies that have examined the use of an OSHMS to minimize the adverse consequences of working hours and schedules.

5.2 Towards an integrated OSHMS to manage working hours and work schedules

We believe that what is needed in the future is a two-tiered approach to minimizing the potential adverse consequences of working hours and work schedules. Companies that lack in-house expertise in work scheduling have a clear need for publically available models, such as the HSE model, that allow them to assess and improve their work schedules (Spencer et al., 2006). In these cases, the company might be legally required to demonstrate that its working hours and schedules reduced risk to the lowest possible or practicable limit. Guidelines would obviously have to be developed on such limits that took account of the potential public/environmental risk, and that covered occupational health as well as safety.

Companies would be allowed to ignore these limits if they could demonstrate that they had set up an adequate OSHMS that was overseen by an OSH committee comprising managers and workforce representatives and was integrated into its Safety Management System. The OSHMS should identify any adverse consequences of the work schedule using data from the company's records, and then implement measures to eliminate or mitigate these and to ensure that the problem levels were kept as low as is reasonably practical. Any OSHMS would probably need to comprise two main phases. The first phase can be conveniently thought of as a "risk assessment phase", during which an appropriate risk assessment of the company would be undertaken. A major component of the risk assessment phase would be to examine all the work schedules from a given period using the best available mathematical model. The risk assessment should integrate the output from this modelling with information obtained from the company's various health and safety records, including sickness absence and any critical incidents. The model output and company records would be validated against one another and an iterative procedure could then be used to optimize an "integrated model".

During this risk assessment phase, the OHS committee would hold frequent, e.g. quarterly, meetings to discuss the main findings and conclusions. These meetings would consider recommendations for improving the work schedules and assess their likely cost-benefit. At the start of the risk assessment phase, these recommendations would be based primarily on the results of the analyses obtained using the mathematical model. However, by the end of the risk assessment phase, which is anticipated to last at least a year, the recommendations would be based on the integrated model, and hence reflect not only the output from the mathematical model, but also the iterative integration of all the other inputs available.

The second phase - integration - would gradually pick up over time as the risk assessment phase tailed off. The first evidence for it would be changes in the work schedules resulting from the OSH committee meetings. These changes would themselves be monitored and the results incorporated into the integrated model. The integration phase would thus be an iterative phase that would continue for the life of the company. Any new or changed work schedules would be carefully monitored and the results incorporated into the integrated model. Health and safety management during this phase would be not only reactive, but also proactive. Thus any proposed new schedules would be investigated using the integrated model to ensure that they minimized any adverse outcomes before their introduction. Further, the multiple inputs into the integrated model would be continuously monitored and subjected to cost-benefit analyses in order to ensure that the model delivered maximum benefits at minimum cost.

The aim would be to fully integrate the OSHMS into the company's Safety Management System as early as reasonably practical. The precise time course for this would, of course, depend on the size of the company and the complexity of the work schedules. It is anticipated that full integration would not normally occur within less than two years of the start of the programme. Finally, an education programme should ideally be implemented during the integration phase. This would be based not only on the available scientific literature, but also on the results of the risk assessment phase. It would be continually revised to take account of the changes in the integrated model, changes to work schedules and the introduction of new schedules, and would be overseen by the OSH steering committee.

5.3 Conclusions

It would appear that traditional prescriptive limitations of hours of work may be of only very limited value in ensuring that the potential adverse consequences of work schedules on well-being, health and safety are minimized. The transport industry is increasingly moving away from prescriptive-based regulation, such as hours-of-work limitations, towards outcome-based regulation. As one Secretary-General of the International Maritime Organization put it: "In simple terms, [an outcome-based] standard may be something like: 'People shall be prevented from falling over the cliff.' By contrast, in prescriptive regulation the specific means of achieving compliance is mandated, for example: 'A one-metre high rail shall be installed at the edge of the cliff'" (cited in A. Smith, Allen and Wadsworth, 2006). A key advantage of outcome-based regulation is that organizations are required to implement the controls that are specifically appropriate to their operating environment.

To date, outcome-based regulations for working hours and schedules have been pioneered largely in the transport sector and have taken the form of FRMS. One of the first was developed by Air New Zealand, which has found a steady decrease in pilot fatigue levels since its implementation in 1985 (Powell, 2004). Perhaps more importantly, a number of improvements have been made to the pilots' work schedules as a result of the FRMS. In most organizations, however, the well-being, health and safety of the workforce is the more important factor, since the potential hazard to members of the general public and to the environment is minimal. We therefore believe that what is needed in the future is the adoption of a more general OSHMS aimed at minimizing the host of potential adverse consequences associated with working hours and schedules.

6. Summary and conclusions

This paper started by considering the theoretical framework pertaining to the impact of working hours and work schedules on a wide range of OSH measures. These are viewed as ultimately stemming from disruptions to sleep, the body clock, and family and social life, but may be moderated by a range of individual, organizational and environmental factors. The potential adverse consequences of working hours and work schedules may be either acute and/or chronic, and in many cases reflect increased levels of fatigue in the individuals concerned. Fatigue is viewed as a biological drive for recuperative rest that requires a period of at least rest, if not sleep, for recovery.

The paper then considered the available evidence relating working hours and work schedules to occupational health and safety. With respect to working hours, it considered the evidence relating to both daily and weekly hours. In both cases, the impact on fatigue was viewed as indicative as much of the opportunity for rest and recuperation as of the number of hours worked *per se*. As might be expected, there was a tendency for the consequences of daily working hours to be more acute in nature than those associated with weekly working hours, although this difference was by no means clear-cut. Somewhat surprisingly, both short and long work weeks were associated with negative outcomes, although in the case of short work weeks this was probably the result of factors other than fatigue.

The opportunity for rest and recuperation was also shown to be fundamental in determining the impact of work schedules. Work schedules that conflict with the normal sleep-wake cycle can result in considerable cumulative fatigue that can only be dissipated if the timing of rest periods allows adequate sleep. The impact of each feature of work schedules was considered separately, although in practice they always occur in combination. Thus, although it is clearly possible to make recommendations for each specific feature, the impact of the features of any given work schedule really need to be considered in combination with one another. For example, a span of five successive 12-hour shifts might be perfectly acceptable if there are frequent rest breaks and they are worked during the day, but totally unacceptable if there are no rest breaks and they are worked at night.

For this reason, a number of mathematical models have been developed to predict the fatigue likely to be associated with particular work schedules. Earlier models were largely based on the theory of the regulation of sleep and wakefulness. More recent, atheoretical models are simply based on the established trends in fatigue and risk associated with particular features of work schedules. In both cases, the major advantage of such models is that they allow an overall assessment of the entire work schedule rather than a piecemeal assessment of its individual features.

Finally, this paper considered the various approaches that have been adopted in an attempt to minimize the adverse consequences of working hours and working time arrangements. Early approaches based on prescriptive limitations of, for example, the maximum permissible number of working hours per day or week would now appear to be of limited value, since they fail to take account of the interactions between different features of work schedules in determining their acceptability. More recently, there has been a move towards more outcome-based regulation, e.g. ensuring that the work schedule does not cause undue fatigue.

In the field of working hours and work schedules, outcome-based regulation has been used primarily in the transport industry, where FRMS have been developed that aim to keep fatigue, and hence risk, to acceptable limits. However, while FRMS may be appropriate in high hazard situations in which the general public is at risk, they do little, if anything, to ensure the well-being and health of the workforce.

For example, FRMS are unlikely to take into account the impact of flexible working time arrangements which, as the current review describes, tend to affect chronic health and well-being, rather than acute fatigue outcomes. We thus conclude by arguing that what is needed in the future is the development of more general OSHMS aimed at minimizing the potential adverse consequences of work schedules.

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