LEADING ARTICLE

The Challenges of Modern Day Work Schedules: Effects on Alertness, Performance, Safety, and Health

Melissa M Mallis, Summer L Brandt, and Mark R Rosekind

Alertness Solutions, Cupertino, CA, USA

Work schedules have evolved over the years due to the increasing demands of around-the-clock activities and technological advancements of society. As a result, individuals are often faced with work schedules that interfere with the "normal" sleep/wake cycles of nocturnally placed sleep and daytime work. Work schedules that oppose this natural biological rhythm result in physiological disruptions leading to sleep loss, degraded performance and mood levels, and increased risks to health and safety. It is estimated that nearly 15 million Americans work non-traditional hours for numerous reasons ranging from increased work demands to increased time for family or social activities. While service-oriented occupations (e.g. healthcare, public safety, transportation) tend to be more commonly associated with shift work, non-standard schedules also exist in modern conveniences (e.g. leisure, hospitality services) and highly technological environments (e.g. energy, nuclear power plants). Individuals reporting insomnia or excessive sleepiness in relation to a work period that occurs during the habitual sleep phase may be diagnosed with shift work sleep disorder (SWSD). SWSD is classified as a circadian rhythms disorder and it is estimated to affect 10% of those employed in shift work. Both non-pharmacological and pharmacological approaches have been identified for the management of the effects of SWSD. A comprehensive management program that involves, for example, a shared responsibility between both the individual and organization is essential for addressing the risks associated with around-the-clock work schedules. Effective management of modern work schedules at both an individual and organizational level offers an opportunity for sleep medicine to improve the health and safety of society. *Int J Sleep Wakefulness* 2007;**1**(1):2–8.

Work schedules in modern day society

Around-the-clock activities required in today's society often result in shifted work schedules that interfere with "normal" sleep/wake cycles of nocturnally placed sleep and daytime work. Although shift work has traditionally included only night work and rotating shift schedules, the modern definition is more comprehensive and has been expanded to include any schedule that can potentially affect both sleep and circadian rhythms. Specifically, any work undertaken outside the traditional 7 AM–6 PM time frame can be categorized as shift work [1]. Table 1 identifies some of the common scheduling factors that disrupt sleep and circadian rhythms, subsequently affecting alertness and performance [2].

According to the US Bureau of Labor Statistics [3], nearly 15 million Americans work alternative shifts outside traditional work hours, including evening shifts (4.7%), night shifts (3.2%), employer-arranged irregular schedules (3.1%), rotating shifts (2.5%), and other non-daytime schedules (1.3%). This comprises approximately 15% of the overall, full-time working population, and it is expected that the number of people working shifted schedules will rise as around-the-clock operations continue to become more common and increasingly accepted as the standard for any work environment.

Shift work schedules are not unique to a single environment and exist in multiple work settings, extending from service occupations to highly technological and safety sensitive settings (e.g. energy and nuclear power plants). The prevalence of shift work is greatest amongst service occupations, such as the protective services, food preparation/serving, and production/transportation/material moving occupations, with leisure and hospitality industries having the greatest proportion of shift workers [3]. The expectation that humans can adapt to any schedule, at any time of the day, while continuing to maintain high alertness and performance levels will become more common,

Address for correspondence: Melissa M Mallis, Alertness Solutions, 1601 South De Anza Boulevard, Suite 200, Cupertino, CA 95014, USA. Email: mmallis@alertsol.com

Table 1. Work-schedule factors that affect sleep, circadian rhythms, and alertness [2].

- Early start times
- Extended work periods
- Amount of work time within a shift or duty period
- <8 h off between work periods
- Number of consecutive work periods
- Insufficient recovery time between consecutive work periods
- Night work through window of circadian low
- Daytime sleep periods
- Day-to-night or night-to-day transitions (schedule stability)
- Changing work periods (e.g. starting and ending times, cycles)
- On-call or reserve status
- Schedule predictability (i.e. available in advance)
- Time zone changes
- Unplanned work extensions

especially since service-providing industries are expected to account for the most new jobs (estimated at 18.7 million of the 18.9 million new wage and salary jobs generated over 2004–2014 period) [4]. However, it is thought that people working non-traditional schedules are more likely to suffer from disturbed sleep and on-the-job sleepiness, and will never fully adapt to their work schedule [1,5]. As a result, physicians can expect to see an increase in the number of patients complaining of difficulties in coping with shift work schedules and experiencing decrements in both mental and physical functioning.

Interestingly, the main reason given by shift workers for working non-daytime schedules is that it is the "nature of the job" [3]. Other reasons include increased work demands and variability in scheduling allowing for more continuous days off and thus increased time for family or social activities. Furthermore, a non-traditional schedule is desirable for some when the timing of the shifted work schedule is opposite to the schedules of other working family members. This schedule flexibility allows the individual to attend to family needs such as childcare and household responsibilities. Additionally, some employers offer an added monetary incentive for non-standard work schedules.

Effects of shift work

Physiological disruption

When people consider the challenges associated with shift work, sleep difficulties are typically one of the first issues identified, since the majority of shift workers complain of disturbed sleep and overall sleepiness [5]. Many believe that if they can "get a handle on their sleep schedule", then all of the other problems associated with shift work would be alleviated. However, adapting to shift work is a more complex issue.

Humans are hardwired to function as diurnal animals with sleep occurring during the nighttime hours. Sleep is most consolidated and efficient when initiated near the rising phase of the melatonin rhythm, which typically occurs during the nighttime hours [6]. However, sleep periods of shift workers more commonly occur when the body is programmed to be awake [7]. There is, consequently, a disruption of the sleep/wake cycle forcing these individuals to override the endogenous biological clock, the circadian pacemaker, which programs them for daytime activity and nighttime sleep. Thus, overall sleep is disrupted with shift workers complaining of both initial (difficulty falling asleep) and middle (difficulty staying asleep) insomnia, although middle insomnia is more frequently reported [1]. This results in the shift worker experiencing continuous partial sleep loss, which can accumulate into a chronic state of sleep deprivation. Some individuals continue to report sleep difficulties, including longer sleep latencies when trying to fall asleep and waking before their desired "wake" time, even after returning to a "standard" schedule [8].

Unlike fixed-day schedules, where work report times typically occur within a few hours of awakening, shift workers are further challenged if they are unable to obtain consolidated periods of recovery sleep within close proximity to starting work. Therefore, the duration of wakefulness before reporting for scheduled work duty is another factor to be considered by shift workers. The longer a person remains awake, the sleepier one becomes [9]. This accumulation of fatigue across the waking hours can then extend into the duty period itself. If the individual keeps a fixed non-standard schedule, sleepiness levels can continue over successive days or weeks and the individual is likely to accumulate a sleep debt [10].

Shift work is also associated with circadian disruption due to the misalignment between the phase of the circadian pacemaker and the sleep/wake cycle. The circadian pacemaker is located in the suprachiasmatic nuclei (SCN) of the hypothalamus and contributes to the control of waking alertness and performance and timing of sleep periods in an approximately 24 h sinusoidal rhythm [11]. On a typical 24-h cycle, with sleep nocturnally placed, performance and alertness variables reach a low point during a trough occurring in the early morning (around 5 AM); a second trough, of lesser extent, is observed in the late afternoon and is often referred to as the post-lunch dip [12]. However, in those working non-standard schedules the circadian system becomes desynchronized; it no longer follows a

regular 24-h pattern and becomes unpredictable. Competing exogenous factors, or zeitgebers (i.e. time givers), from the day/night cycle and a day-oriented society continually push a non-standard schedule back towards its usual diurnal orientation. The most powerful zeitgeber is the light/dark cycle.

It is the light/dark cycle that is largely responsible for entraining circadian rhythms to a 24-h day [6]. Light information is transmitted through a retino-hypothalamic tract to the SCN of the hypothalamus, which is the location of the circadian pacemaker. Therefore, light acts as a powerful stimulus in the regulation of circadian rhythms, contributing to a stable phase relationship between circadian rhythms and the external 24-h day [6]. The light/dark cycle of a day-oriented society, with sleep nocturnally placed, is in direct opposition to the shift work cycle. In laboratory settings, controlling light/dark exposure to mimic cycles associated with shift work (i.e. light at the subjective night and dark during the subjective day) should promote adaptation to working at night and sleeping during the day; however, conflicting light/dark signals and social interactions during actual 24/7 operations prevent circadian adaptation. Thus, shift workers rarely adapt fully to their work schedule.

Overall, the sleep/wake cycles of shift workers are constantly altered between work days and non-work days. The demands of work scheduling drive the scheduled sleep/wake times on work days. However, on non-work days, shift workers tend to revert to a daytime schedule. This schedule change is influenced by the physiological need for recovery sleep during nighttime hours as well as domestic factors of social and family obligations [1].

Performance changes

The inherent nature and mechanisms of the circadian clock allows only a gradual re-entrainment process when working a shifted schedule. Conflicts between the endogenous circadian system and environmental time cues affect this re-entrainment and those working shifted schedules are not able to adapt to schedule changes quickly. As a result, they experience performance and physiological changes that occur in a manner that is unpredictable [11], and can be seen within as little as 2 h of sleep loss [13]. Performance levels and sleepiness are worsened due to the effects of sleep loss and to the difficulties associated with maintaining alertness and high cognitive functioning at an adverse circadian phase. This is of concern since maintaining optimal performance and alertness levels in a work setting is critical to maintaining safety.

When regular 24-h sleep/wake cycles are maintained and sleep is protected, neurobehavioral performance tests do not demonstrate significant diurnal variation during waking hours from 1–2 h after awakening to 1–2 h before sleep onset [14]. However, research has shown that significant decreases in neurobehavioral performance can occur when sleep/wake patterns are disrupted or when work times are scheduled several hours before or after peak circadian performance levels. These changes include [15–17]:

- Slowed reaction times.
- Cognitive slowing.
- Deficits in frontal lobe functioning.
- Degradations in response accuracy and sleep.
- Short-term memory difficulties.

Decrements in neurobehavioral functioning are especially apparent during late night and early morning hours [18].

An increased occurrence of work-related injuries has been associated with extended work days, especially during night shifts [19]. For example, the near melt-down at the Three Mile Island (Harrisburg, PA, USA) nuclear power plant on March 28, 1979, occurred during the early morning hours of 4–6 AM. The individuals failed to detect the loss of core coolant that resulted from a stuck valve in one of the unit reactors [20,21]. The catastrophe at the Chernobyl (Ukraine) nuclear plant also occurred during the early morning hours (around 1 AM) and again was attributable to human error [22,23]. These two examples of the failure to monitor processes accurately are partially attributable to working at an adverse circadian phase and with an accrued sleep debt. These work related incidents and accidents have not only been observed in highly technological environments, but also seen in everyday activities including driving and medical services [2,18].

Another common response observed in those undertaking shift work is uncontrollable sleepiness, in which individuals have no voluntary control over falling asleep and commonly experience microsleeps (short, uncontrollable episodes of sleep) [24,25]. Such involuntary asleep periods affect safety not only during work periods but also during the drive to and from work [26]. Individuals working non-standard schedules are more likely to have a higher exposure to nighttime driving, increasing the chances of drowsiness while driving and decreasing the ability to effectively respond to stimuli or emergency situations. In fact, research has demonstrated that the odds of falling asleep or being involved in an accident while driving are doubled for rotating shift workers [27].

Adverse mood and health effects

Although individuals report increased sleepiness with the progression of sleep loss, research has shown that these subjective estimates are unreliable; generally, humans are

Table 2. Health and safety risks associated with shift work.

Health effects
- Increased risk of heart disease
- Increased risk of breast cancer in women
- Gastrointestinal difficulties
- Psychological stress
- Increased sick days
- More likely to smoke and/or use alcohol
- Disruption in family/social time
- Decreased quality of life
- Shift work sleep disorder

Neurobehavioral
- Accuracy and speed degrade
- Narrowing of attention
- Unable to integrate information
- Impaired logical reasoning
- Decreased attention span
- Decreased cognitive performance
- Microsleeps

Subjective
- Increased subjective fatigue ratings
- Mood deteriorations
- Acceptance of lower standards

sleepier than they report [25,28]. Therefore, an individual working a non-standard schedule is not likely to be aware of increasing sleepiness levels. For example, if an individual is in a highly engaged environment, involving physical activity or interaction with other individuals, the underlying sleepiness may not be as noticeable and that person may rate themselves as being more alert than their physiological responses would indicate.

Fatigue can also affect overall mood (See Table 2). Sleepy individuals often show deteriorations in mood and are less able to communicate and interact socially with others [17,29]. The effects of shift work on overall mood are experienced not only by the person working the non-standard schedule but can extend to their family and/or friends. A continuous challenge faced by shift workers is the requirement to be awake and active when most people are sleeping and then to sleep when others are awake. This can result in decreased social and family activities, which can in turn result in a more negative mood and increased depression [30].

In addition, adverse health effects are more frequently seen in shift workers (Table 2). Although the specific underlying causes and mechanisms are not firmly established, possible explanations include, but are not limited to, chronic circadian misalignment and digestive responses being out of sync with the circadian phase. These adverse health effects include increased risk of heart disease, occurrence of gastrointestinal difficulties, risk for breast cancer in women, ringing in the ears, and a two-times greater rate of gastric ulcers compared with non-shift workers; these effects can be long term [30–33]. Furthermore, it has been reported that night shift workers are 62% more likely to smoke and have a 40% increased use of alcohol compared with non-shift workers [34]. The use of these two substances can further contribute to sleep difficulties. Additionally, sleepiness associated with shifted schedules can have both direct and indirect costs in the workplace, with increases in absenteeism and work accidents.

Shift work sleep disorder

Prevalence

A subset of shift workers report insomnia when trying to sleep and excessive sleepiness during waking hours, no matter how much sleep they obtain. Individuals in whom these symptoms persist may be suffering from a condition known as shift work sleep disorder (SWSD). Those who have a strong need for stable sleep and wake times are particularly vulnerable to SWSD.

The prevalence of SWSD varies depending on the occurrence of shift work within a specific population. A recent study estimated that 10% of the shift work population suffers from SWSD [30]. Of an estimated 15 million shift workers in the US, nearly 1.5 million may be affected by SWSD [30]. However, the same study also found that up to 32% of shift workers experience symptoms of insomnia or excessive sleepiness (the minimum criteria for SWSD), thus the prevalence of SWSD might in fact be closer to 5 million. It is believed that the rate of SWSD will continue to rise with increasing advances in modern technology [1].

Diagnosing SWSD

According to the International Classification of Sleep Disorders, SWSD is a disorder of the circadian rhythms characterized by symptoms of insomnia and excessive sleepiness that occur in relation to work schedules [35]. The lack of adaptation to a work/rest schedule results in loss of a normal sleep/wake cycle. Consequently, sleep is not fully restorative and individuals can experience significant amounts of sleep loss [35]. Although SWSD is defined as a circadian rhythms disorder, it is more complex and can be considered a combination of three factors [1]:

- Sleep.
- Circadian.
- Domestic.

Table 3. Summary of diagnostic criteria for shift work sleep disorder according to the American Sleep Disorders Association [35].

1. The patient has a primary complaint of insomnia or excessive sleepiness.
2. The primary complaint is temporally associated with a work period (usually night work) that occurs during habitual sleep phase.
3. Polysomnography and the Multiple Sleep Latency Test demonstrate the loss of a normal sleep/wake pattern (i.e. disturbed chronobiological rhythmicity).
4. No medical or mental disorder accounts for the symptoms.
5. The symptoms do not meet criteria for any other sleep disorder producing insomnia or excessive sleepiness (e.g. time-zone change [jet lag] syndrome).

The affected individual suffers from sleep loss, circadian disruption, as well as a degree of domestic/social isolation due to the non-standard schedule. The five criteria defined by the American Sleep Disorders Association for the diagnosis of SWSD are summarized in Table 3 [35].

The minimal criteria for diagnosing SWSD are primary complaints of both insomnia and excessive sleepiness associated with a work schedule that occurs during the habitual sleep phase. If these two criteria are met, there is justification to evaluate the patient's sleep/wake history to further explore the existence and severity of SWSD. A sleep specialist can measure polysomnographic activity during the shifted sleep period as well as monitor levels of sleepiness during regular waking hours using the Multiple Sleep Latency Test (MSLT).

Based on these diagnostic criteria, the severity of SWSD can be categorized as mild, moderate, or severe [35]. Mild forms of SWSD are associated with 1–2 h of sleep loss per day, with individuals taking 10–15 min to fall asleep on the MSLT (normal range of MSLT scores in healthy adults is 10–20 min). Although those suffering from moderate forms of SWSD also report daily insomnia, excessive sleepiness is reported to interfere with daily workplace performance and activities that require a certain level of attention, such as driving. Sleep loss for these individuals is approximately 2–3 h/day, with MSLT scores in the 5–10 min range. Severe forms of SWSD result in extreme levels of excessive sleepiness and it is not uncommon for the individual to fall asleep during social or physical activities. The daily complaint of insomnia, associated with >3 h of sleep loss per night, is associated with severe social and operational performance decrements. These individuals tend to fall asleep in < 5 min.

Table 4 lists a number of sample questions that can be used by physicians as a starting point when assessing a patient for SWSD.

Table 4. Sample questions for the diagnosis of shift work sleep disorder.

1. Does the patient report:
   a. excessive sleepiness or difficulty staying awake during routine tasks (e.g. reading, watching television, or driving)?
   b. excessive sleepiness interfering with work-related tasks?
2. What is the patient's work schedule? Does it overlap with habitual sleep time (i.e. work schedule occurring between 6 PM-7 AM)?
3. During what time frame does the patient normally sleep?
4. Does the patient meet diagnostic criteria for any other sleep disorders associated with excessive sleepiness or insomnia?
5. Does the patient suffer from any other medical or mental disorder associated with excessive sleepiness?

Treatment options

Increasing total sleep time and ensuring ample recovery sleep are the main management goals for sleep loss associated with working non-traditional schedules or SWSD. These can be achieved through both non-pharmacological and pharmacological approaches. The most common non-pharmacological options include:

- Strategies to help increase total sleep times.
- Strategic napping.
- Appropriately timed bright light exposure.

Developing pre-bedtime routines, optimizing the sleep environment (e.g. eyeshades to create a dark environment, earplugs to reduce noise levels), and keeping stable sleep/wake cycles are relatively simple strategies that can help individuals maximize their total sleep amounts. Strategic napping is an effective strategy that can be used to maximize the total amount of sleep obtained within a 24-h period [25]. Napping prior to a scheduled duty period reduces the number of continuous hours awake and can also be used during a low workload portion of the duty period or the circadian low poin tc help improve alertness and performance over a short period of time [25]. Appropriately timed exposure to, and avoidance of, bright light can have both alerting and shifting benefits [6]. Specifically, avoidance of light immediately after a work period and prior to a sleep period can help individuals adapt to shift work [36]. For example, wearing sunglasses on the commute home and going to bed in a darkened room shortly after a work period are simple strategies to avoid bright light and promote adaptation. Additionally, exposure to light during the night shift not only has a direct alerting affect but will also

promote adaptation to the shifted sleep schedule. However, as light of a specific quantity and duration can shift the circadian rhythm to an earlier or later time, caution should be used to ensure that the level of light exposure has the desired effect.

Pharmacological approaches used to assist those in management of their SWSD include:

- Caffeine.
- Hypnotics.
- Melatonin.
- Modafinil.

Caffeine is the most widely used wake-promoting agent [37]. However, it is important to be aware of the individual differences associated with the effective dose and duration of effect. Hypnotics have a short half-life and can be used to increase daily sleep amounts. However, all of the standard cautions (e.g. lowest effective dose, used for shortest amount of time, monitoring of effectiveness and adverse effects) associated with hypnotic use should be considered. Research has shown that melatonin can be used as an effective aid in altering the circadian rhythms for shift workers [38]. Modafinil, which has been approved as a wake promoting medication by the US Food and Drug Administration, can be used to treat excessive sleepiness associated with SWSD. It has been shown to increase alertness and improve performance and clinical symptoms when taken 1 h prior to a scheduled work period [39].

In some cases use of a single treatment option will be effective, but with more severe levels of SWSD a combination of approaches might be required. However, the effectiveness of specific treatment approaches is determined by individual differences [1]. Not all individuals will react in the same manner and/or over the same time to a single or combination of strategies.

Addressing the performance, health, and safety risks associated with shift work is a complex issue. One effective approach is a comprehensive alertness management program involving a shared responsibility between the individual and organization [2,40]. Individual efforts could focus on obtaining information on the topics of sleep loss, circadian disruption, sleep disorders, and potential alertness strategies, while organizations could facilitate education and evaluate the role of schedules. Without an accepted shared responsibility, it is likely that efforts to manage the risks will not be effective.

More importantly, both individuals and organizations play a role in the diagnosis and treatment of sleep disorders. It is important for individuals to be aware of the symptoms of SWSD and potential treatment options, as well as toremain compliant with prescribed treatments. Furthermore, organizations should provide information on SWSD and develop policies that support individuals diagnosed with this condition.

Conclusion

As technology continues to develop and evolve in our increasingly 24/7 society, a growing number of individuals will be faced with working schedules outside of "normal" daytime hours. The timing of their sleep/wake schedules deviates from the normal cycle of nocturnally placed sleep and daytime work and commonly fluctuates between work and non-work days. This sleep and circadian disruption combined with conflicting light and social cues contribute to individuals not adapting fully to a shift work schedule. As a result, performance is significantly degraded and there are increased risks to both safety and health, with consequent increases in the risk of sleepiness-related incidents and accidents.

It is not uncommon for shift workers who keep these non-standard schedules to suffer from SWSD, varying from mild to severe forms. Using specific criteria, sleep specialists can diagnose the existence of the SWSD and can work with patients to prescribe a treatment regime including both non-pharmacological and pharmacological options to help manage their challenges with insomnia and excessive sleepiness during waking hours. When assessing the benefits of an effective treatment approach, it is also important to consider individual differences in how patients respond as well as the limitations of the overall approach.

Managing modern work schedules at the individual level, through diagnosis of medical conditions and specific treatment regimes, is only one component in addressing performance, health, and safety challenges associated with shift work. A comprehensive approach that includes organizational level involvement and a shared responsibility with individuals offers an even greater opportunity for sleep medicine to improve the health and safety of society.

Disclosures

The authors have no relevant financial interests to disclose.

References

1. Monk TH. Shift work: basic principles. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:673–9.
2. Rosekind MR. Managing work schedules: an alertness and safety perspective. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:680–90.
3. Bureau of Labor Statistics. Workers on flexible and shift schedules in 2004 Summary [online]. 2005 [cited 2005 Oct 19] Available from URL: www.bls.gov/news.release/flex.nr0.htm
4. Bureau of Labor Statistics. Tomorrow's jobs [online]. 2005 [cited 2007 Jan 8]. Available from: www.bls.gov/oco/oco2003.htm
5. Åkerstedt T. Shifted sleep hours. *Ann Clin Res* 1985;**17**:273–9.
6. Czeisler CA, Buxton OM, Khalsa SB. The human circadian timing system and sleep-wake regulation. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:375–94.

7. Åkerstedt T. Is there an optimal sleep-wake pattern in shift work? *Scand J Work Environ Health* 1998;**24**(Suppl 3):18–27.
8. Marquie JC, Foret J. Sleep, age, and shiftwork experience. *J Sleep Res* 1999;**8**:297–304.
9. Rosa RR, Bonnet MH. Performance and alertness on 8-hour and 12-hour rotating shifts at a natural gas utility. *Ergonomics* 1993;**36**:1177–93.
10. Dinges DF, Pack F, Williams K et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. *Sleep* 1997;**20**:267–77.
11. Van Dongen HPA, Dinges DF. Circadian rhythms in sleepiness, alertness, and performance. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:435–43.
12. Folkard S, Monk TH, editors. Circadian performance rhythms. In: *Hours of Work – Temporal Factors in Work Scheduling*. John Wiley, New York, NY;1985:37–52.
13. Carskadon MA, Roth T. Sleep restriction. In: *Sleep, Sleepiness and Performance*. Monk TH, editor. John Wiley, New York, NY;1991:155–67.
14. DeRoshia CW, Greenleaf, JE. Performance and mood state parameters during 30 day 6° headdown bed rest with exercise training. *Aviat Space Environ Med* 1993;**64**:522–7.
15. Webb WB, Agnew HW. Sleep: effects of a restricted regime. *Science* 1965;**150**:1745–7.
16. Dinges DF. Probing the limits of functional capability: the effects of sleep loss on short-duration tasks. In: *Sleep, Arousal, and Performance*. Broughton RJ, Ogilvie RD, editors. Birkhauser, Boston;1992:177–88.
17. Bonnet MH. Acute sleep deprivation. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:51–66.
18. Mitler MM, Carskadon MA, Czeisler CA et al. Catastrophes, sleep and public policy: consensus report. *Sleep* 1988;**11**:100–9.
19. Smith L, Folkard S, Poole CJ. Increased injuries on night shift. *Lancet* 1994;**344**:1137–9.
20. President's Commission. *Report of the President's Commission on the accident at Three Mile Island: the accident at Three Mile Island*. Washington, DC: U.S. Government Printing Office; 1979.
21. Moss TH, Sills DL, editors. *The Three Mile Island accident: lessons and implications*. The New York Academy of Sciences; 1981.
22. United States Senate Committee on Energy and Natural Resources. *The Chernobyl accident*. Washington, DC: U.S. Government Printing Office; 1986.
23. United States Nuclear Regulatory Commission. *Report on the accident at the Chernobyl Nuclear Power Station*. Washington, DC: U.S. Government Printing Office; 1987.
24. Torsvall L, Åkerstedt T. Sleepiness on the job: continuously measured EEG changes in train drivers. *Electroencephalogr Clin Neurophysiol* 1987;**66**:502–11.
25. Rosekind MR, Graeber RC, Dinges DF et al. *Crew factors in flight operations IX: effects of planned cockpit rest on crew performance and alertness in long-haul operations* [Technical Memorandum No. 108839]. Moffett Field, CA: National Aeronautics and Space Administration; 1994.
26. Wierwille WW, Wreggit SS, Kirn CL et al. *Research on vehicle-based driver status/performance monitoring: development, validation, and refinement of algorithms for detection of driver drowsiness, final report*. [Report No. DOT HS 808 247]. Washington, DC: National Highway Traffic Safety Administration; 1994.
27. Gold DR, Rogacz S, Bock N et al. Rotating shift work, sleep, and accidents related to sleepiness in hospital nurses. *Am J Public Health* 1992;**82**:1011–4.
28. Dinges DF. The nature of sleepiness: causes, contexts and consequences. In:. *Perspectives in Behavioral Medicine: Eating, Sleeping and Sex*. Stunkard A, Baum A, editors. Lawrence Erlbaum, Hillsdale, NJ;1989:147–80.
29. Rosekind MR, Gander PH, Connell LJ, Co EL. *Crew factors in flight operations X: alertness management in flight operations education module*. [Technical Memorandum No. 2001-211385] Moffett Field, CA: National Aeronautics and Space Administration; 2001.
30. Drake CL, Roehrs T, Richardson G et al. Shift work sleep disorder: prevalence and consequences beyond that of symptomatic day workers. *Sleep* 2004;**27**:1453–62.
31. Knutsson A. Health disorders of shift workers. *Occup Med* 2003;**53**:103–8.
32. Arendt J, Stone B, Skene DJ. Sleep disruption in jet lag and other circadian rhythm-related disorders. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:659–72.
33. Hansen J. Increased breast cancer risk among women who work predominantly at night. *Epidemiol* 2001;**12**:74-77.
34. Trinkoff AM, Storr CL. Work schedule characteristics and substance use in nurses. *Am J Ind Med* 1998;**34**:266–71.
35. American Sleep Disorders Association. International classification of sleep disorders, revised: diagnostic and coding manual. Rochester, MN: American Sleep Disorders Association; 2005.
36. Burgess HJ, Sharkey KM, Eastman CI. Bright light, dark and melatonin can promote circadian adaptation in night shift workers. *Sleep Med Rev* 2002;**6**:407–20.
37. Wesensten NJ, Killgore WD, Balkin TJ. Performance and alertness effects of caffeine, dextroamphetamine, and modafinil during sleep deprivation. *J Sleep Res* 2005;**14**:255–66.
38. Scheer FA, Cajochen C, Turek FW, Czeisler CA. Melatonin in the regulation of sleep and circadian rhythms. In: *Principles and Practice of Sleep Medicine*. Kryger MH, Roth T, Dement WC, editors. Elsevier, Inc., Philadelphia, PA;2005:395–404.
39. Walsh JK, Randazzo AC, Stone KL, Schweitzer PK. Modafinil improves alertness, vigilance, and executive function during simulated night shifts. *Sleep* 2004;**27**:434-9.
40. Rosekind MR, Gregory KB, Mallis MM. Alertness management in aviation operations: enhancing performance and sleep. *Aviat Space Environ Med* 2006;**77**:1256–65.