

Sleep/Wake Cycle and Circadian Disturbances in Shift Work: Strategies for Their Management—A Review

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Abstract

Introduction: There has been a growing concern about the ability of individuals to maintain adequate levels of performance over long work shifts, particularly when those shifts span night-time hours. It has, therefore, become expeditious to understand and apply principles of circadian rhythms in order to establish simple, rational and appropriate strategies to help our shift workers maximise their performance and minimise their health problems under the various shift work regimes. This review sought to outline several principles of circadian rhythms and the sleep/wake cycle and some possible strategies to manage disturbances in the sleep and performance arising from shift works. **Methods:** Many studies in this field had been carried out. The present review concerns studies which elucidate the general circadian principles as well as those which may provide helpful information applicable for us in the work environment we are living in. **Results:** It has been found that shift workers invariably suffer from a constellation of symptoms, which can sometime severely compromise their ability to perform optimally during their shift work. There are many factors that influence the sleep/wake cycle and thus, the performance of shift work. These include 1) circadian factors, 2) type of shift work, 3) how a person adapt to circadian disruption, 4) ageing, 5) sleep factors and 6) social and domestic factors. **Conclusions:** Several possible strategies could be adopted to improve sleep and performance. These include 1) appropriate scheduling of shift work, 2) proper consideration of the speed of shift rotation, 3) strategies for sleep and napping, 4) installing appropriate lighting at the workplace, 5) the use of sleeping pills/hypnotics such as melatonin and melatonin agonists.

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Introduction

Humans have primarily been active/awake during the day and inactive/asleep at night. The discovery of artificial light and introduction of electric power generator have made available a continuous and reliable source of light throughout day and night. Therefore, man can now remain active during normal sleep hours and vice versa. With the increasing intensity in the race for economic survival, especially during this period of economic downturn, many entities, including the military, in all countries, have increasingly to provide full range of services 24 hours a day, 7 days a week. Hence, there is a substantial proportion of the population who has to work permanently at night, or on schedules requiring a rotation of day, evening and night work.^{1,2}

There has been a growing concern about the ability of individuals to maintain adequate levels of performance over long work shifts, particularly when those shifts span night-time hours. Shift workers inevitably suffer from a constellation of symptoms that can sometime severely compromise their ability to perform optimally during their shift work. In general, it was noted that performance decrement was more likely to be found on reasoning tasks, on non-stimulating tasks and in the area of medicine, in doctors with less experience.¹ The largest single factor contributing to shift-workers' problems is sleep disturbance, especially the inability to sleep when they were supposed to.¹ Such changes, inherent to shift work operations, may lead to chronic difficulties and a number of health and social problems for shift workers. Studies have shown that

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shift workers have a higher incidence of sick leave, a higher rate of visits to clinic at work site, and poorer scores on a variety of health indices.¹ Sleep problems are certainly the most sensitive indices of health dysfunction in shift workers.¹ Gastrointestinal complaints are much more frequent among shift workers compared to day workers.¹ Among the other long-term side effects of shift work reported are an increase risk of ischaemic heart disease,³ menstrual problems, infertility and loss of libido.¹ Employees' quality of life also suffers: higher rates of divorce and suicide, increased use of alcohol and drugs, low morale, general feeling of malaise exacerbated by the lack of satisfaction in the domestic and social areas of their lives.⁴ An increased risk of accidents is related to the time of shift work, tending to be higher among workers in the night shift.⁵

The endogenous circadian clock of most shift workers does not adapt fully to changes in the sleep-wake rhythm imposed by different shift works and this factor is considered to be responsible for many of the reported health problems.^{2,6} Circadian disruptions arising from shift work can affect coordination and memory, and judgement is diminished during night-time shift, resulting in lost of productivity.⁷ The Associated Professional Sleep Societies (APSS) has concluded that night-time operators' fatigue was a contributing causal factor in 4 well-known recent industrial accidents (i.e. Exxon Valdez, Bhopal, Chernobyl and Three Mile Island), which all occurred between midnight and 5 o'clock in the morning.⁸

There are many factors that influence the circadian rhythms and the sleep/wake cycle, including socio-economic and environmental factors such as the day/night cycle peculiar to each country. Hence, it is important that appropriate research be carried out to address the circadian rhythm and sleep/wake cycle disturbances and their impact on workers' performance and health in each country. Large and varied segments of our society, including doctors, nurses, production workers, air-traffic controllers, port controllers, and military personnel in the three services, are involved in shift duties. It has, therefore, become expeditious to understand and apply principles of circadian rhythms in order to establish simple, rational and appropriate strategies to help our shift workers maximise their performance and minimise their health problems under the various shift work regimes. This review sought to outline some of the principles of circadian rhythms and the sleep/wake cycle and some possible strategies to manage disturbances in these functions.

Circadian Rhythms and the Sleep/wake Cycle

Many physiological and behavioural functions occur in different rhythmic patterns over a 24-hour cycle in man. The sleep/wake cycle, which normally involves sleeping at night and awakening during the day, is an example of such

circadian rhythms.⁹ Many of these circadian rhythmic functions involve hormones, and their secretions exhibit circadian and ultradian rhythms. Such hormones include cortisol secreted by the adrenal gland, melatonin from the pineal glands and hormones from the pituitary gland.¹⁰⁻¹²

The suprachiasmatic nuclei (SCN) are known to be the primary site controlling the sleep/wake cycle.¹³ The SCN-pineal-gland axis is responsible for interpreting changes in the pattern of the light/dark cycle that, in turn, affect the biological rhythm of sleep.¹⁴ This circadian pacemaker for the sleep/wake cycle acts via the secretion of the hormone, melatonin, from the pineal gland. It is well known that melatonin is secreted under circadian and ultradian rhythms.¹⁰ These rhythms are very much affected by exposure to light.¹⁰ Under normal circumstances, its secretion is initiated by the onset of darkness, at about 2100 hours, and its levels remain high throughout the night and only began to fall upon waking up and exposure to bright light during the day.¹⁵ A disruption or a change in the light exposure will, in turn, induce internal desynchronisation between circadian rhythms and thus, sleep.⁹

Both melatonin and cortisol exhibit different rhythms and have different ultradian frequencies, suggesting an intrinsic difference in the mechanisms controlling their secretion.^{10,11,16} Despite these, their secretory profiles seem to be temporally related. Melatonin began to rise around 2100 hours when cortisol was at its lowest, it peaked when cortisol began to rise, and it began to decrease when cortisol reached its peak. These observations support the suggestion that although both hormones have different ultradian frequencies, they are likely correlated because of their dependence on the 24-hour organisation of the day.¹⁰

In addition, it is known that some circadian pacemakers take several days to adjust to a large abrupt shift of sleep/wake and light-dark cycles. For example, studies that instituted a 12-hour out-of-phase shift showed that cortisol secretion remained unchanged for 3 to 4 days and only began to shift after that.^{11,17}

Factors Influencing the Sleep/wake cycle and Performance

Many factors determine whether an individual will or will not cope with shift work. Some of those factors are fixed (e.g. age or circadian type of the individual) and some are adjustable (e.g. shift schedules or social factors); and these factors can be classified as follows.¹⁷

Circadian Factors

The circadian clock controlling sleep/wake cycle runs on a cycle that is slightly longer than 24 hours. In addition, the circadian system of shift workers is constantly subjected to conflicting synchronisers, such as the intensity of light, and

the timing of shifts that tend to impair their ability to adjust to the new imposed sleep/wake schedule, particularly when these signal are changed rapidly.

Type of Shift Work

On quickly rotating schedules (lasting between 2 to 3 days), shift workers suffer from circadian misalignment, since circadian rhythms do not adapt quickly. Very slow rotating (lasting at least 1 to 3 months) shift workers, on the other hand, adapt more easily. Permanent night workers should be a group that maintains a nocturnal orientation. However, this is not the case even after years on the job, since on days off, night workers quickly return to a diurnal orientation due to family commitment as well as essential socialisation.¹⁸

How a Person Adapts to Circadian Disruption

Circadian types of the individuals are one of the best predictors of those who are likely to have shift work-coping problems.¹⁹ Individuals of the “morning type”, those who tend to wake up early and sleep early, seem to have a lower tolerance of shift work than “evening types”. Indeed, they are less alert during the night shift and do sleep shorter periods during daytime compared to “evening types”, those who wake up late and stay up late at night.¹⁹

Ageing

The weaker internal circadian synchronisation of older people, plus their tendency of retiring early and rising early, probably explains why they are less tolerant of shift work.¹⁷ Ageing also significantly decreases the ability to recover after several night shifts.¹⁷

Sleep Factors

Disruption of circadian rhythms affects most shift workers, but only 20% to 30% of them tolerate it very badly, suggesting that additional coping factors might be important. Many of the unspecified complaints of night workers, such as fatigue, malaise, difficulty concentrating, and irritability, can result from sleep loss.¹ In general, about 60% to 70% would have some complaints about their sleep: most of them report difficulties falling and staying asleep, poor quality of sleep, and difficulties staying awake at work.

Sleep after night work is usually shorter than sleep after day work.²⁰ The length of daytime sleep is significantly shorter in night workers and rotating shift workers, with highly fragmented sleep.¹⁷

Sleep during daytime may be altered by both endogenous and exogenous factors. Endogenous factors include high and rising body temperature, high circulating levels of hormones associated with wakefulness (like cortisol),²¹ and low levels of hormones associated with sleepiness (like melatonin). Exogenous factors include traffic, children

playing, and household noise.

Employers often like to have the day shift starting at 0600 hour which requires the employee to wake up at 0430 hours and thus involves some degree of sleep loss. Other factors are alcohol and sleeping pills taken to help falling asleep and whose use is correspondingly higher in shift workers.¹

Social and Domestic Factors

Part of the distress of shift work is due to social factors, like frequent absence from the family with disruption of its organisation, insufficient recreation, compromise of parenting and sexual partner role.⁴ Male or female shiftworkers often fail to cope with home maintenance, resulting in family tension and preoccupation for the shift worker, which increase the strain of shift work even more.²⁰ Shift workers often have to compromise their sleep during their off-period to interact with family members, hence resulting in further sleep disruptions.^{4,20}

Possible Strategies to Improve Sleep and Performance

By applying knowledge gained from understanding the circadian rhythms and the sleep/wake cycle, several strategies could be adopted to improve sleep and performance of shift.²⁰

Scheduling of Shift Work

Since the natural endogenous period of the human circadian clock is longer than 24 hours, the human system appears to adjust more rapidly to phase delays than to phase advances in the sleep/wake cycle. Thus, clockwise rotations of shift work (morning, afternoon, night) seem preferable than counter clockwise (morning, night, afternoon).²² Another reason for clockwise rotation, especially in rapid shift rotation (changing of shift every 2 to 3 days), relates to the amount of time off between shifts. Delays between shifts necessarily result in breaks of at least 24 hours at each shift change, while most advancing systems only incorporate 8 hours break between two rotations, which may severely restrict the sleep duration. Rescheduling can, therefore, consist of modifying shift starting times. It has been shown that a delay of as little as 1 hour in shift starting times can improve the early morning shift workers' sleep and alertness.^{23,24} Whether such a delay would affect the evening and night shift workers have not been studied.

In entities, shift workers are not only required to work over 24-hour cycle, but the rotation of shift may involve several segments within the 24-hour day. For example, for air-traffic controllers, both civilian and military, as well as in many services of the military, shift schedule may involve, 3-hour on, 3-hour off, followed by 3-hour on again, and other combinations. The results suggest that sleep in between the short shifts are difficult to come by and hence, there is an accumulation of fatigue.²⁵ Proper research on the best

shift routine in these situations may help to arrive at better routine to best fit the particular work station so as to minimise sleep/wake cycle disturbances as well as maximise performance, alertness and output which are crucial in some of these professions.

Speed of Shift Rotation

There is an unresolved debate concerning the ideal length of shift rotations. In Europe, fast-rotating schedules are favoured, while in the USA, slow-rotating schedules are more common. Both types of shift schedules have their advantages and inconveniences. Advantages of rapid rotations (e.g. 3 days) include small number of consecutive nights of work resulting in less accumulation of sleep deficit, one of the inconveniences being that the circadian system of the workers never adapts to the imposed work schedule. Advantages of slow rotations (e.g. 3 weeks) include better adaptation of the circadian system to the work schedule, but one of the inconveniences is the gradual build up of sleep loss. Weekly rotations represent probably the worse compromise since such schedules do not allow complete resynchronisation of the circadian system while they give enough time to build up a sleep debt. One way to resolve this issue of scheduling is to consider the task that the worker is asked to perform.²² Tasks with high memory loads such as visual-attentive tasks as in radar tracking will be performed relatively well during the night even in diurnally-oriented workers.²⁶ In contrast, task involving serial searches, inspection or driving are particularly badly performed in unadjusted people, who would benefit from slow-rotating schedules.²²

Sleep and Napping

Adequate day-to-day management of sleep is fundamental for shift workers if they want to avoid spending most of their off-days catching up on sleep. Shift workers should enforce regular sleep hours with appropriate bedtime rituals and adequate sleep hygiene procedures.²⁷ Naps taken during time-off may help to offset the sleep debt typically associated with shift work.²⁸ Brief naps taken during extensive periods of long work may enhance subsequent performance. Time and duration of those naps seem critical: they should ideally be located before performance starts to deteriorate and should not be too long to avoid sleep inertia after the nap, a phenomenon frequently observed in people awakened from deep stages of sleep.²⁸ A short nap of about 30 to 50 min taken in the early hours of the morning during night shift was found to improve alertness.²⁹ Two-hour as well as 4-hour naps have been found to be beneficial for improving performance, mood, and alertness of workers on prolonged and extended work.^{28,30}

Lighting at the Workplace

In modern and urban society like Singapore, many offices

are devoid of natural light from the sun. In its place, artificial light, usually fluorescent white light is used. The amount of lighting in these offices will affect the circadian rhythm of melatonin and hence the sleep/wake cycle. Many offices may have light intensity of less than 300 lux. The human visual system is particularly sensitive to light of wavelength between 500 to 530 nm (i.e. in the colour range of green/yellow). It was also noted that plasma melatonin levels are more readily suppressed by such light of wavelength between 500 to 530 nm than by various other hues of the same intensity.³¹ For example, the suppression is 76% greater than for 600 nm (orange to red). As green light is more potent in suppressing melatonin output, a more subjectively acceptable intensity may have similar effects on melatonin output compared to, for example, full spectrum artificial white light of a somewhat higher intensity.³¹ In some situation where dim red light is routinely used, for example onboard a naval ship, the use of dim green light could be considered.

Studies have shown that carefully timed exposure to bright light can shift human circadian rhythms independently of changes in the sleep/wake cycle. Bright light (greater than 2500 lux) has been shown to be effective relative to dim light (less than 500 lux) in controlling winter depression.³² Other studies have shown that exposure to moderate bright light (a 4-hour pulse of 2000 lux starting at 2000 to 0400 h) during a long night shift could improve the alertness and performance of the shift workers.³³ A more recent study has shown that increasing the light intensity to between 1230 to 5700 lux and exposing workers on night shift to this light for 3 hours, has led to better alertness during the night shift which are results of better sleep during the day and less accumulation of fatigue.³⁴

Bright light therapy is thought to work through the retinae, even when the eyes are closed, as the eyelids are translucent to light.³⁵ Sleep loss often leads to photosensitivity, and artificial light of the type needed to suppress melatonin can be distressing to sleep-deprived subjects, so they avoid the full light.³¹ In this respect, exposure to high intensity light flashes, around 300,000 lux of exceeding short (nanosecond) duration, has been employed so as not to leave the retinal after-effects.³¹

Several human phase-response curves to light have been generated, using either single or repeated pulses of bright light of different duration.³⁶ Using those data, Czeisler's group^{37,38} performed a simulated night study, in which they tested the efficacy of daylight levels of illumination supplemented by rigid darkness enforcement during the daytime sleep episode of the subjects. This treatment induced large phase delays in circadian rhythms of body temperature, plasma cortisol, subjective alertness, and cognitive performance.^{37,38} When applied to the real

workplace, use of bright light has proven to enhance employees' vigilance on the night shift, allowing daytime performance levels to be attained. Adjusting the biological clock with light also makes it easier to sleep during the day, effectively preventing sleep deficit. It is important to keep in mind that inappropriately timed exposure to bright light in the morning (for instance, during travel back home from night work) can phase advance the circadian clock of night workers and reverse some of the beneficial phase-delaying effects of night-time exposure to bright light. Ideally those shift workers should be advised to wear dark sunglasses on their way home.³⁶

The Use of Sleeping pills/hypnotics

Short-acting benzodiazepines could improve sleep and alertness of night shift workers. However, chronic use of any sedative-hypnotic should not be advised because of the potential development of tolerance and drug-dependency insomnia.³⁹⁻⁴² Zolpidem-induced prophylactic naps have been found to be beneficial for improving performance, mood, and alertness of workers on prolonged sleep-deprivation. However, post-nap grogginess persisted for about 2 hours after Zolpidem-induced naps, hence, this may compromise performance under operational conditions if insufficient time for awakening is planned for.³⁰

Melatonin and Melatonin Agonists

Melatonin has a diverse range of physiological effects in humans. Reported effects include modulation of the sleep/wake cycle, thermoregulatory, cognitive, cardiovascular and immune systems.⁴³ However, there is currently a lack of empirical clinical studies to support these melatonin's effects in men.⁴⁴ For the induction of sleep, what the optimal dose of melatonin is remains unclear; most studies have used doses that produce supraphysiological blood levels. The timing of melatonin administration is also important. Melatonin has few immediate side effects except drowsiness, but the effects of chronic administration are unclear.⁴⁴

Whether melatonin possesses hypnotic properties remain inconclusive.⁴⁵ The mechanism of action of melatonin is different from that of classical hypnotics. Unlike benzodiazepine hypnotics, melatonin effects on sleep are not antagonised by the benzodiazepine antagonist flumazenil.¹⁴ The effects of melatonin on sleep may be indirect, mediated both by a lowering of core body temperature,¹⁴ thus increasing the propensity to sleep, and by an effect on circadian rhythm organisation.¹⁴

Melatonin has been shown to shift the phase of the circadian system, and to reduce jet lag.^{44,46} It may also have a hypnotic effect independent of its circadian effect, probably related to its hypothermic effect.¹⁴ Its use before bedtime has been shown to improve sleep, mood and performance.⁴⁷

It also improves both sleep quality and sleep duration during the day, and self-rated alertness in the early morning hours.⁴⁶ It is, however, unclear whether the beneficial effects of melatonin were due to a phase delay of circadian rhythms or to a lowering of body temperature during daytime sleep, which reduced arousal. In a recent study, melatonin was shown to have only modest benefit to emergency physicians working night shifts.⁴⁸ It is unlikely that melatonin use in normal people will be helpful. However, it probably will be effective in sleep disorders of the circadian type, or sleep disorders, such as in the elderly, in which there is a component of circadian rhythm disorganisation.⁴⁶

Summary

The orientation of rotation, time and duration of shift work have great impact on workers' performance and sleep/wake rhythms. For more efficient output, clockwise rotation should be used, rotations of shift at intervals of 4 to 12 weeks would allow workers to adapt to the change in rhythm. Evidence so far, support that in early morning shift, it is more appropriate to start the shift slightly later than 6 o'clock, so as not to disrupt the sleep of workers. Whether similar delays for afternoon and night shifts are effective have yet to be studied. The duration of each shift normally varies from 8 to 12 hours, and in some cases extended to 36 hours. Some studies appear to suggest that two 12-hour shifts are better than three 8-hour shifts,⁴⁹⁻⁵¹ while others suggest that it is equivocal.⁵²⁻⁵⁴ In long duration shift, introduction of short nap of at least 30 minutes at appropriate time when performance begins to deteriorate would be helpful to enhance the alertness of the individuals. Whether short nap should be applied to all long shift work has to be tested in different settings. Lighting plays an important role in the regulation of the sleep/wake cycle. Especially during late night shift, by ensuring that lightings at the work place have sufficient intensity, greater than 350 lux, one can ensure better regulation of the circadian pacemaker for sleep and thereby improve alertness, sleep and performance. Many offices and work-station have light intensity of 350 or less lux (personal observation and measurements); and it has been reported in some offices to be closer to 500 lux.⁵⁵ In cases where circadian disruption affects adversely the sleep pattern of the workers, the use of hypnotic drugs such as melatonin, zolpidem and benzodiazepines may be considered. However, their use should be viewed with caution.

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