Shift work: Consequences and management

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Shift work is a form of work scheduling involving a process in which a group of workers succeed each other at the same workstation in shifts. The shifts can be organized either in a rotating, a continuous or a discontinuous fashion. Notwithstanding the patterns of work scheduling, it has been unequivocally accepted that shift work in general disrupts biological rhythms, sleep and social life. In addition, shift work leads to a number of clinical and non-clinical problems. It retards human performance and increases the chances of occurrence of major industrial accidents. This review presents some recent data dealing with the deleterious consequences of shift work and discusses the possible ways to optimize human shift work. Eventually, optimization of human shift work would minimize the occupational health hazards among shift workers, maximize their performance and augment the productivity of their organization.

DESPITE the fact that working at night has been prevalent at least since the Roman time and had extended with the Industrial Revolution (2.8% night workers in 1904, in Western Europe)[1], in the first few decades of the nineties technology progressed tremendously and also the methods of production, in order to satisfy increasing needs of the contemporary society. This phenomenon probably evolved methods leading to a more effective use of the available natural resources and manpower. Many industrialized countries, then introduced and adopted *shift work* system with a view to optimize utilization of human resources and to ensure continuity in operation of industries and various other production houses[2]. Consequently, the population of shift workers grew steadily and is still growing at a pace faster than before. At present nearly one-fifth of the total global work force works in shifts. The reasons for growing number of shift workers are manifold: (i) Modern industries depend upon expensive machines and continuity in their functioning is extremely mandatory and cost-effective. Therefore, these machines have to be manned by workers round-the-clock; (ii) Shift work determines dimension of the return on capital investment, and (iii) Quality in the current-day lifestyle demands immediate and round-the-clock service from various indispensable sectors such as public health, transport, security (both internal and external), communication and media. All these sectors need men to be posted/deployed round-the-clock. Thus, shift working has become a routine feature and will be absolutely inevitable in future, if the present character and the rate of growth and development in industries are to continue.

What is shift work?

'The term *shift work* is defined as an arrangement of working hours that uses two or more teams (shifts) of workers, in order to extend the hours of operation of the work environment beyond that of the conventional office hours. The varieties of shift work include: stable/permanently displaced working hours in which the work schedule used does not require a person to normally work more than one shift (including night work), rotating shift work in which an individual is normally required to work more than one shift, changing from one shift to another and unscheduled working hours. On-call shift is also a special form of shift work, where in case of emergency the particular group of workers are called for their duties. The most widespread shift system is when production is organized in eight-hour shifts, called morning, evening and night shifts[2].'

According to the International Labour Office[3], shift work is defined as: 'A method of work organization under which groups or crews of workers succeed each other at the same workstations to perform the same operations, each crew working a certain schedule or *shift* so that the undertaking can operate longer than the stipulated weekly hours for any worker. Often the term is used when more than one work period is scheduled in a workday or when most of the working hours fall outside the standard workday, such as evening, night or weekend shifts'.

Prevalence

The past few decades have witnessed a tremendous growth in the population of shift workers, specially in developed and highly industrialized countries. Developing countries are also not free from experiencing this phenomenon[4]. In USA, almost two decades ago over 27% of male workers and 16% of female workers were working in shifts[5]. At the comparable time in Great Britain the proportion of employees in the manufacturing industry doing shift work increased from 12.5% in 1954 to 25% in 1968

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(ref. 6). In the Netherlands and France the shift workers were estimated to be around 19 and 21%, respectively, in the seventies[7]. In Canada, at present about 2 million people (23%) of the 8.5 million full-time workers, work in shifts.

Surprisingly, similar types of statistics are not available for India. Census[8] does not differentiate night shift workers/rotational shift workers from the entire population of industrial workers. It is indeed essential that a database should be created separately for all types of shift workers in India.

Modulatory factors

Several studies have been made on the problems of shift workers in relation to three important modulatory factors, namely circadian, sleep and social/psychosocial/domestic factors[9–19]. These factors have been considered to be important in determining the coping ability of a worker to shift work. According to Monk[10], each of these three factors consists of several other sub-factors (Figure 1). All these factors interact with each other and produce considerable influence on workers' tolerance to shift work. However, Monk's list is not exhaustive. There may be many more factors yet to be identified. It is also important to underline that some, but not all of these factors are present or relevant simultaneously in case of an individual shift worker. Some of them are job-specific, while others depend upon the internal constitution of the individual itself (Figure 2).

Intolerance to shift work

The severity of clinical problems may have varying magnitudes among individual shift workers. In other words, while some workers tolerate shift work better, others are intolerant[16,20]. On the basis of intensity of medical complications, it is possible to classify shift workers having good tolerance (with neither complaints nor medical problems), poor tolerance (with medical complaints) and very poor tolerance (severe clinical problems). Clinical intolerance to shift work was defined[15,21,22] by the existence and intensity of a set of medical complaints: (i) sleep alterations; (ii) persisting fatigue; (iii) changes in behaviour; (iv) digestive troubles and (v) The regular use of sleeping pills. Symptoms (i), (ii) and (v) are present in any intolerant subject. Clinical intolerance to shift work appears to be independent of an individual's age and length of shift working experience[14,15,21,23]. On the contrary, there are some who believe that aging is associated with a decreased tolerance to shift work, critical age being on an average 40–50 years[24–29]. There is a kind of ambiguity in using the term tolerance. 'Clinical intolerance' relates to symptoms quoted above, while 'tolerance at large' involves also the incidence of diseases, which seem to occur more frequently in shift workers compared to non-shift workers. In this paper, the term tolerance has been used with reference to complaints or symptoms quoted above.

The term 'internal desynchronization' was used by Aschoff and Wever[30] to describe a process during which the period (τ) of a circadian rhythm may differ among variables in apparently healthy human subjects. '. . . the circadian system can split into components that run with different frequencies . . .'[30]. An example of internal desynchronization in a very poor tolerant shift worker (age

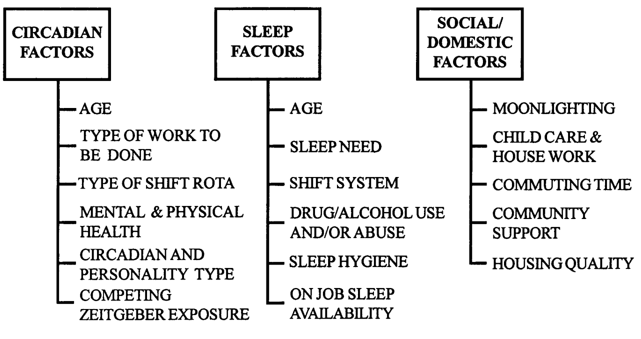

Figure 1. Factors and sub-factors that are known to modulate coping ability of workers to shift work (based on Monk[10]).

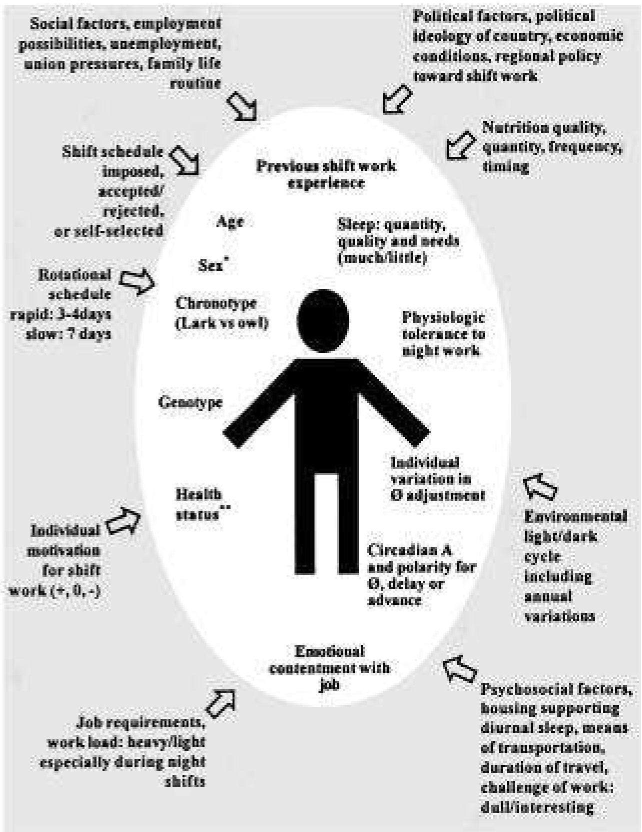

Figure 2. Major factors underlying tolerance to shift work. The ring delineates the interface between exogenous (external) and endogenous (internal) factors (from Reinberg and Smolensky[22]).

31 years) who had shift work experience of 3 years is illustrated in Figure 3. Both day-to-day acrophase (peak time) locations and power spectra show that oral temperature, right- and left-hand grip strength had non-24 h τs, while sleep–wake rhythm had a τ = 24 h. Another example exhibited internal desynchronization in a subject (age 39 years) with good tolerance to shift work, who had been shift working for 14 years. Variables, namely sleep–wake, oral temperature and left-hand grip strength rhythms had a period (τ) equal to 24 h, while right-hand grip strength had non-24 h period (Figure 4). This clearly reveals that both internal desynchronization of circadian rhythms and development of intolerance do not depend upon the length of shift work experience. More intensive studies are needed to evolve a generalization. However, intolerance to shift work appears to accompany a state of internal desynchronization among several circadian rhythms. Motohashi[31] as well as Pati and Saini[32] and Chandrawanshi and Pati[33] confirmed the phenomenon of internal desynchronization among intolerant shift workers dwelling in Japan and India, respectively.

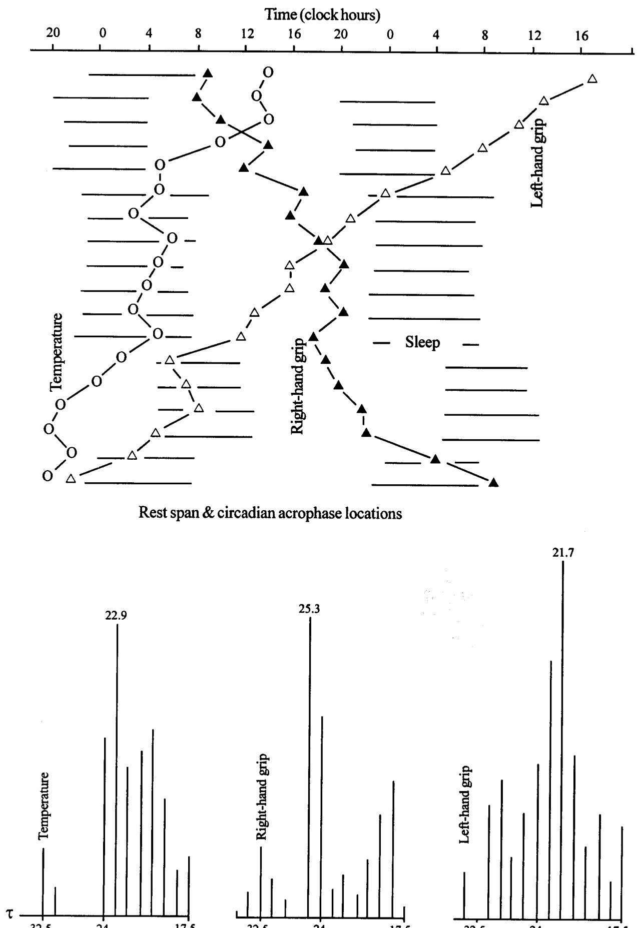

Figure 3. (Top) Rest span and circadian acrophase locations of three variables; (Bottom) Power spectra of the same variables. Horizontal bar, Double plot of hours of rest span (from lights-out to lights-on); O, Acrophase location of oral temperature; ▲, Right- and Δ, Left-hand grip strength. The tallest of the lines of any spectrum and the figure at the top correspond to the prominent period of that variable. Subject: oil refinery operator; right handed; age, 31 years; shift working for 3 years; very poor tolerance to shift work (from Reinberg *et al.*[15]).

Consequences of shift work—Alteration/ modulation of circadian rhythms

It is unequivocal that most of the animals, including man, under natural conditions exhibit circadian rhythms with a period of approximately 24 h and a timing device keeps these rhythms synchronized with the light–dark cycle and other oscillatory components of the environment[34–36]. This phenomenon is called external synchronization. Such rhythms are expressed in various physiological, biochemical, immunological, psychological and behavioural variables[37–49]. Rapid travel across several time zones (jet lag) and rotational shift work are the best-known situations when synchronization breaks down and internal

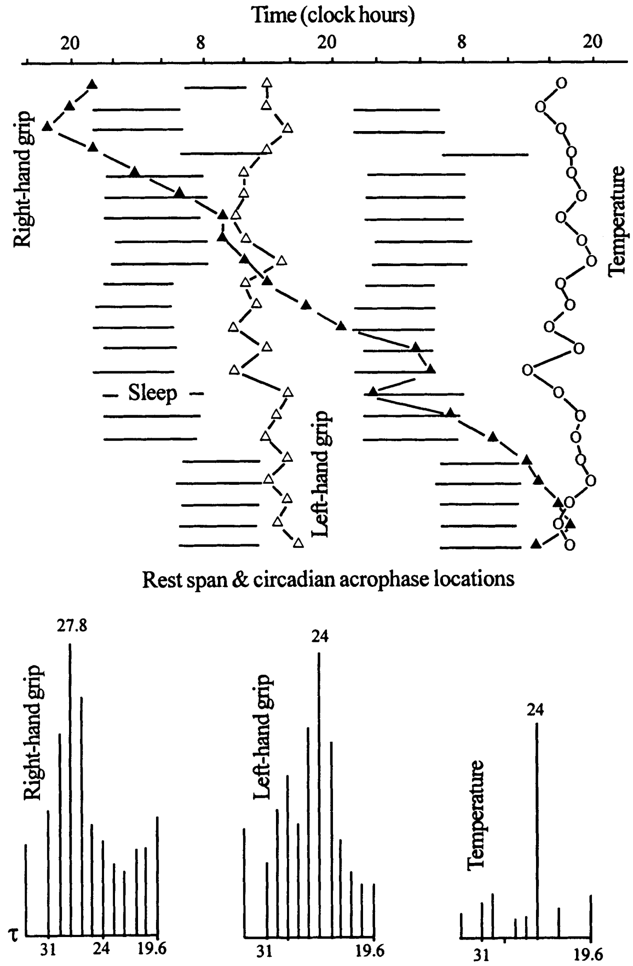

Figure 4. Same as Figure 3. Subject: oil refinery operator; left handed; age, 39 years; shift working for 14 years; good tolerance to shift work (from Reinberg *et al.*[15]).

rhythms no longer oscillate with frequencies similar to the environmental cycles. In this state, internal bodily rhythms are termed externally desynchronized[50]. However, there are instances when many bodily rhythms despite being externally desynchronized, remain internally synchronized. Here, internal rhythms have similar frequencies, although not circadian. There are, however, several compelling situations that cause complete temporal disorder characterized by both external as well as internal desynchronization[14,32].

There is sufficient evidence to prove that rotational shift work affects human health and performance by disrupting circadian rhythms and by causing numerous alterations in human behaviour and physiology[51–53]. Internal desynchronization of several rhythms in shift workers has been reported[14–16,20,31,32,54–57]. Figure 5 demonstrates rhythm desynchronization of several variables among various groups of shift workers. The desynchronization is often marked by alteration in other important rhythm parameters such as phase, amplitude and 24-h average of given variable(s).

Phase

Shift workers most often experience a phase shift in their bodily rhythms. It may depend on many factors. The most crucial among others are their exposure to the type of work schedule and natural time cues[58]. The major effect of shift work involves a phase shift of the circadian rhythm resulting as a consequence to a shift in the zeitgeber from the phase shift of synchronized periodic signals. Several studies have documented a phase shift in the body temperature circadian rhythm among shift workers[14,17,26,59–61] (Figures 6 and 7). While Matsumoto and Morita[61] recorded a phase advance of the body temperature circadian rhythm in older shift workers following night duty, Härmä *et al.*[17] documented the same in the oral temperature and sleepiness rhythms, irrespective of age, when the shift workers moved from the morning shift to the night shift. However, there is an interesting relationship: the larger the phase shift, the smaller is the amplitude. Reinberg and Smolensky[22] and Reinberg *et al.*[14,15] have substantiated the above by documenting that subjects with good tolerance have large-amplitude circadian rhythm (in body temperature) associated with small phase shift of acrophase. In contrast, poorly tolerant individuals should have small amplitude associated with large phase shift of acrophase. In other terms they seem to be more prone to desynchronizing their circadian rhythms than subjects with good tolerance.

Amplitude

The amplitudes of circadian rhythm in various variables of shift workers undergo changes compared with those of the diurnal workers. Reference is made to the rhythm's amplitude (circadian peak to trough mean difference and cosinor) and its end points estimated on an individual basis and longitudinal studies, e.g. a 5-day span of time. We stress this methodological aspect since day-to-day variability may obscure the reported phenomenon when time series are too short. Reinberg *et al.*[14,15] suggested that alteration in circadian amplitude of oral temperature rhythm in shift workers probably ideally reflects on the

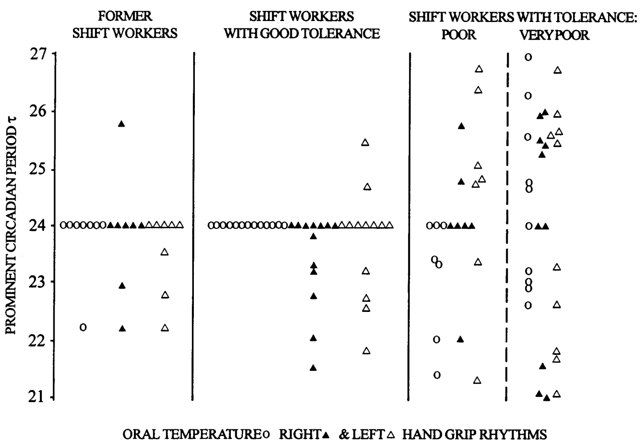

Figure 5. Prominent circadian period resulting from power spectrum analyses for all the variables and subjects plotted with regard to each of the four groups and their tolerance to shift work (from Reinberg *et al.*[15]).

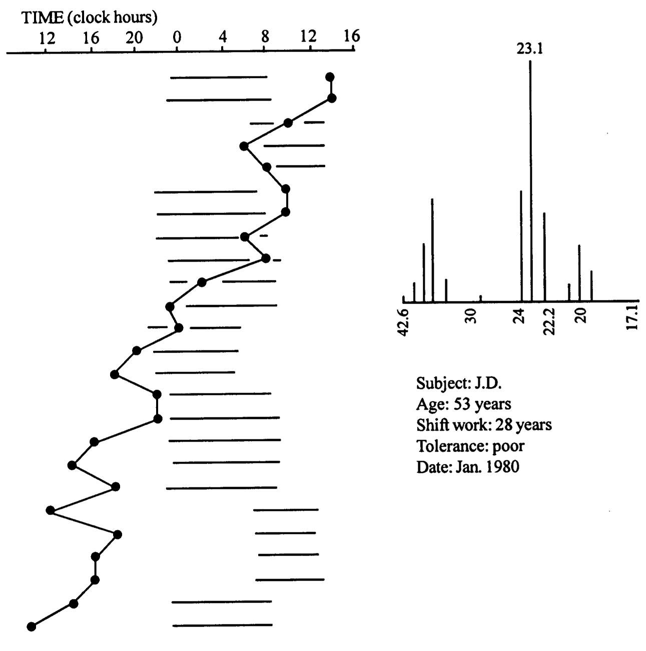

Figure 6. Desynchronization of the oral temperature circadian rhythm of subject J.D. when his tolerance to shift work was poor. (Left) Horizontal bars represent both duration and location of rest (lights-off to lights-on) governed by shift schedules (rapid rotation); black dots and solid lines represent day-by-day acrophase (Ø) location (peak time) of the temperature rhythm. (Right) Power spectrum of the temperature rhythm with period τ in hours (from Reinberg *et al.*[14]).

tolerance to shift work. They further emphasized that amplitude alteration could be taken as an index to assess an individual worker's shift work coping ability. It is suggested that individuals with large circadian amplitude are more tolerant to shift work, since it helps the subjects to maintain their internal synchronization[14,21,23]. It seems that persons who possess weak circadian time structure, i.e. a rhythm with low amplitude, are more prone to develop biological intolerance to shift work later in life. However, those with a strong (high-amplitude) time structure are the least prone[62]. Reinberg *et al.*[15] reported large circadian amplitude of oral temperature, right- and left-hand grip strength and heart rate in good-tolerant shift workers than with poor tolerant shift workers. They also documented relationship between changes in circadian amplitude and desynchronization of several rhythms such as oral temperature, left-hand grip strength and heart rate. Touitou *et al.*[63] documented decreased circadian amplitude of serum cortisol in shift workers, whereas the amplitude of the melatonin rhythm was larger in shift workers than in controls. They also reported alteration in rhythm amplitudes of prolactin and testosterone in shift workers with a fast-rotating shift system.

Recently, Chandrawanshi and Pati[33] observed an increase in circadian amplitudes of several rhythms such as skin temperature, heart rate and peak expiratory flow rate in shift workers of a cement factory. They studied the circadian time structure of shift workers in two different spells. There was a lag of about 16 months between two spells. During this period the factory remained almost closed for nearly 8 months, with moderate to low-profile activities in the remaining months. At the time of the study in the first spell the shift workers had already experienced about 14 months of industrial slough. However, when the same shift workers were re-examined in the second spell after about 16 months, they experienced about 30 months of cumulative industrial slumber that accompanied 8 months of near-complete closure. However, during this period, shift workers were assigned shift duties, irrespective of the workload and activity of the factory. Despite being on rotational shift duties, whenever there was no workload, they slept at their work places. In other words, they behaved reasonably like day workers with nocturnal sleep during the period between two spells of studies. Therefore, in the shift workers of the cement factory the once desynchronized rhythms in several variables became resynchronized. The process of resynchronization also accompanied an increase in the circadian amplitudes of these rhythms[33].

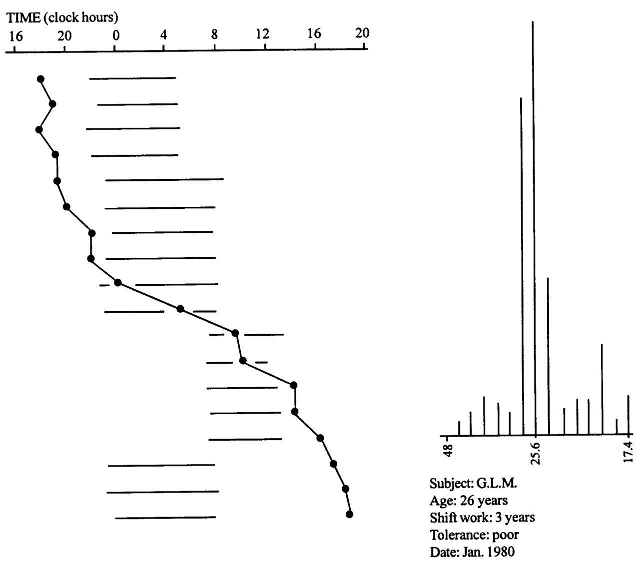

Figure 7. Desynchronization of the oral temperature circadian rhythm of subject G.L.M. with a poor tolerance to shift work. Data presentation as in Figure 6 (from Reinberg *et al.*[14]).

24-h average of circadian rhythms

The 24-h arithmetic averages of several circadian rhythms have been shown to alter in shift workers. Of the random number addition speed (RNAS) rhythm, circadian mesor (24-h average of RNAS rhythm) increased in shift workers compared to control subjects[32,56]. This suggests that shift workers took longer time than their day-working counterparts to do the aforesaid jobs (Figure 8). Shift workers with lower 24-h average of negative moods and fatigue rhythms tolerate night shifts better. They also show fewer respiratory and psychosomatic–digestive complaints[64]. The 24-h arithmetic average also undergoes a change when a shift worker is shifted from one work schedule to another. Further, the magnitude of change may also depend upon the direction of schedule rotation. Härmä *et al.*[17] observed that the 24-h arithmetic average of the oral temperature rhythm decreased slightly and that of the sleepiness rhythm increased highly significantly from morning to the second night shift in various age groups.

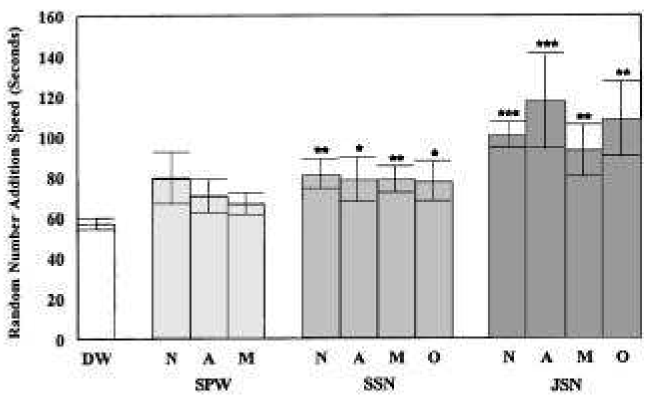

Figure 8. Twenty-four hour average ± 1 SE of random number addition speed (in seconds) in day workers and various groups of shift workers during different shifts. DW, day workers; SPW, shift workers from a steel plant; SSN, senior shift working nurses; JSN, junior shift working nurses; N, night shift; A, afternoon shift; M, morning shift; O, off day (from Gupta[259]).

Physiological rhythms

Several studies have documented the phenomenon of desynchronization among various physiological rhythms, namely axillary temperature or oral temperature or skin temperature, heart rate, subjective fatigue, attention and drowsiness, peak expiratory flow and grip strength of both hands in shift workers from oil refineries and steel manufacturing, chemical engineering, photographic film manufacturing and cement industries[14–16,33,65] (Figures 9 and 10). Further, the same has been reported for oral temperature, drowsiness, heart rate and performance circadian rhythm in shift-working Indian nurses[32,56,57] (Figure 11). Time estimation circadian rhythm was also found to be disrupted in shift workers[66].

Desynchronization of circadian rhythms attributed to shift work may lead to several clinical complications. It may produce disastrous chronopharmacologic effects such as impaired metabolism and impaired responsiveness to medications[52]. It has also been reported that it may make shift workers more prone to sufferings, notably myocardial infarction, exacerbation of insulin-dependent diabetes, epilepsy and neuropsychiatric disorders[52,67].

Phillips and Brown[68] have documented that disrupted circadian rhythms and fatigue from rotating shifts have been implicated as a cause of traumatic injuries. According to Monk[10], desynchronization of circadian system affects the mental and physical health, longevity of the worker as well as public safety. However, there have been no categorical proofs to suggest that prolonged shift work may alter longevity of shift workers. Michel-Briand *et al.*[69] documented more cases of depression and affective illness in retired shift workers than in retired day workers, in whom cardiovascular and locomotor problems have been reported to be more predominant. It could well be that in predisposed subjects an internal desynchronization is associated with symptoms which are common to both depression and shift-work intolerance.

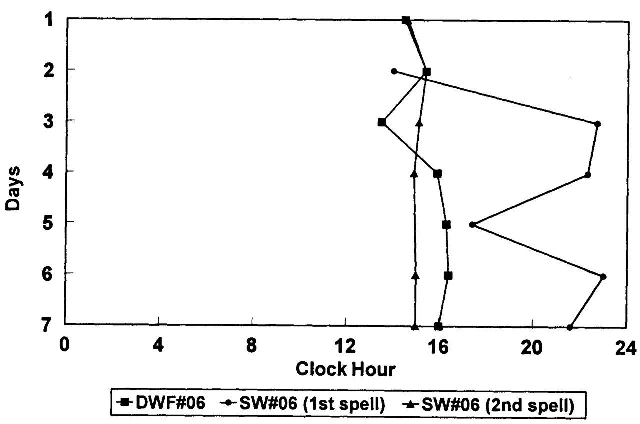

Figure 9. Illustrative example showing day-to-day changes in acrophases of skin temperature of a day worker (DWF #06) and a shift worker (SW #06 in 1st and 2nd spells of studies) from a cement factory.

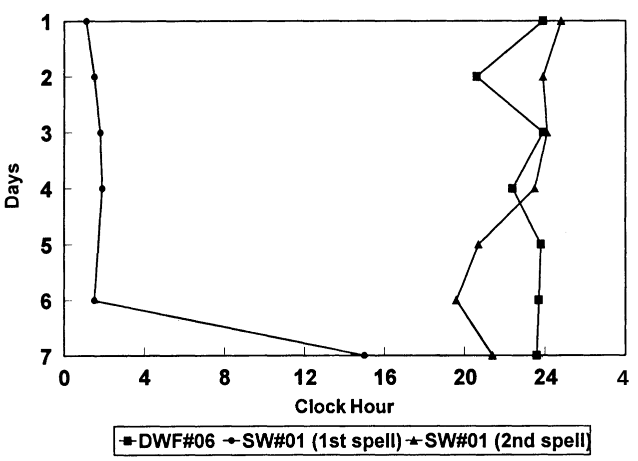

Figure 10. Illustrative example showing day-to-day changes in acrophases of subjective drowsiness of a day worker (DWF #06) and a shift worker (SW #01 in 1st and 2nd spells of studies) from a cement factory.

Consequences on sleep

Sleep disorder

Scheduling of sleep timings is a major concern in the life of shift workers, particularly if their work schedule includes night work among others[70–74]. Tepas and Mahan[75] have suggested that night shift workers suffer more often

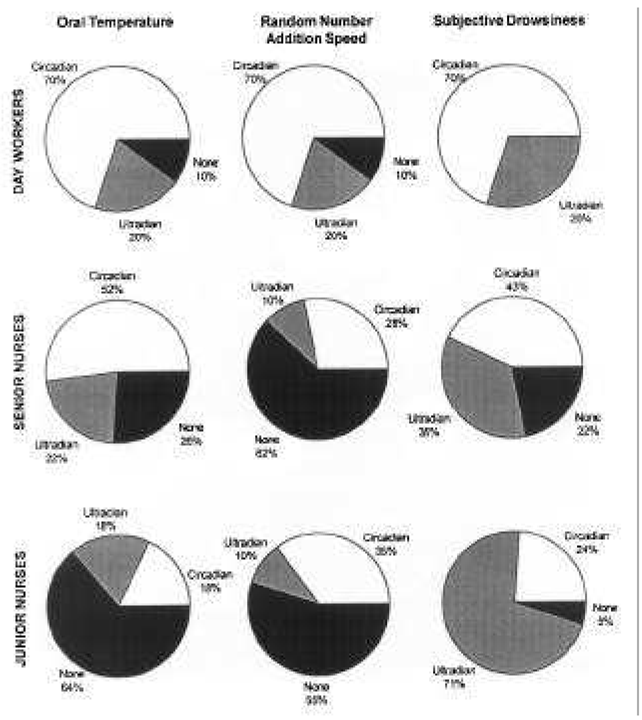

Figure 11. Detection of circadian (τ = 24 h), ultradian (τ = 12 h) and non-circadian/non-ultradian (τ ≠ 24 h and/or ≠ 12 h) rhythms in 3 variables, namely oral temperature, random number addition speed and subjective drowsiness in day workers, senior shift working nurses and junior shift working nurses. Data have been pooled in the respective groups (from Gupta[259]).

from insomnia-like sleep disorder. This abnormality is characterized by difficulty in falling and staying asleep. Their rigorous work helped build a model that proposes that night shift work results in acute partial sleep deprivation. The latter causes a decrease in performance leading to decreased productivity. Fröberg *et al.*[76] have shown that a 72-h sleep deprivation does not obliterate circadian rhythms. However, while parameters of physiological rhythms (e.g. adrenaline, body temperature) remained unchanged, there was a trend of decrease in performance (logical reasoning, calculation tests) and increase in self-rated fatigue and sleepiness. Glenville *et al.*[77] have shown that one night sleep deprivation impairs performance in choice reaction time and simple reaction time. Continuous work in the night shift may lead to chronic partial sleep deprivation. In addition to performance decrements, chronic sleep deprivation may lead to many other clinical complications. It has been reported that total sleep deprivation may lead to fatal/devastating consequences such as death, as reported in non-human primates[78]. The association between shift work and sleep disruption results in adverse medical and psychological consequences[52]. In many studies, a majority of shift workers admit to having experienced involuntary sleep on the night shift, whereas this is rare in day-oriented shifts[79–81]. The rotating shift workers find it difficult to sleep during daytime due to noises at home and in the residential community[24,82,83].

Sleepiness

Poor sleep, both quantitative and qualitative, leads to sleepiness. Sleepiness has been defined as a drive towards sleep[84] and is traditionally expressed in subjective terms, although there are clearly pronounced behavioural and physiological expressions. It has been documented that the main causes of sleepiness in workers working in irregular work hours are the circadian phase modulation[85,86], the amount of prior wakefulness[85], the length of work shift[87], the speed of rotation[88] etc.

Czeisler *et al.*[89] and Zulley *et al.*[90] demonstrated that subjects who have the option to select their own preferred sleep/wake pattern under total isolation from external time cues exhibit circadian rhythm of sleep. Dijk and Czeisler[91] have suggested that a natural disposition of circadian rhythm of sleep seems to consolidate sleep and wakefulness. Several investigators have documented a significant circadian rhythm in subjective drowsiness/sleepiness in apparently healthy human subjects[16,56,92]. The drowsiness rhythm in these subjects exhibits peak between 21.00 and 23.00 h, with a pronounced circadian period. However, in case of shift workers, rhythm in sleepiness desynchronizes externally as well as internally[16,56]. Shift workers do have problems with sleep management, specially because they attempt to have sleep at chronobiologically unsuitable time of the day. The problems include difficulty in initiating sleep and staying asleep. According to Czeisler *et al.*[89], sleep is very difficult at the acrophase (maximum) of the body temperature rhythm and very easy at its nadir (minimum). Shift work disrupts the normal relation between rest/activity and the circadian regulation of bodily functions[93]. Among the most obvious effects of this disruption is disturbed sleep and increased sleepiness[94,95]. Åkerstedt[96] reported sleepiness peak during the early morning in between 04.00 and 07.00 h in night-shift workers. A secondary peak has also been observed in sleepiness in the afternoon[97].

Lavie[98] has documented a 24-h rhythm in sleep propensity function (SPF). A 7-min sleep trial is applied every 20 min around the clock. The amount of sleep obtained in each trial, plotted as a function of time, results in SPF. The largest peak occurs at night (around 04.00 h), while a second peak, smaller than the one at night, occurs in the afternoon (around 16.00 h).

There are several studies which suggest that the majority of shift workers experience sleepiness during the night-shift work, whereas day work is associated with no or marginal sleepiness[86,99–105]. Usually, the relationship between subjective sleepiness and performance is a close one, with major performance lapses occurring at the higher levels of sleepiness[106]. Åkerstedt[86] emphasized that not only is sleepiness experienced during the night shift, a considerable increase in sleepiness has also been observed in workers while they return to day work soon after the night shift. Furthermore, when the starting time of the morning shift is advanced, more sleepiness is experienced during the day[107–109] (Figure 12). This also decreases sleep length and sleep quality[107,108]. An early start of morning shift at around 06.00 h has particularly deleterious effects upon alertness[110].

Sleep disturbances

In general, sleep disturbance is one of the major complaints of shift workers[66,111–116]. Sleep disturbances and

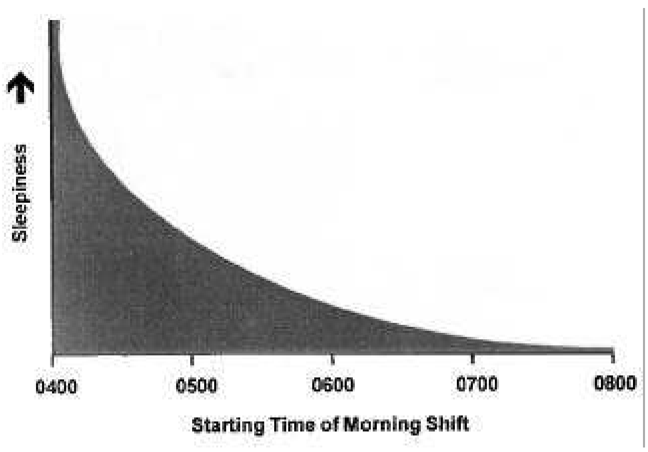

Figure 12. Idealized diagram showing relationship between amount of sleepiness and starting time of the morning shift (based on Hak and Kampman[107], Moors[108], Kecklund *et al.*[109]).

sleepiness are caused mainly due to displacement of the circadian wakefulness to trough timing, where the sleep-promoting properties of the circadian rhythm are at their maximum[86,112]. The proportion of shift workers suffering from sleep disturbances is usually above 50%, compared to 5–20% for day workers[95]. The sleep disturbances reported by shift workers are both qualitative and quantitative and may lead to increased use of alcohol and hypnotics[52]. A number of studies demonstrated that compared to the permanent day workers, sleep quality and quantity seem to be poorer for the rotating shift workers[72,115,117–120]. Tilley *et al.*[121] and Fischer *et al.*[122] concluded that the quantity and quality of sleep are degraded and deteriorated as a result of working at night.

Sleep length

Several studies on experienced night-shift workers have repeatedly revealed that night work decreases sleep length and may result in an increase in sleep complaints[103,121,123–127]. The reduction in sleep length found among night-shift workers is perhaps one of the most important findings in the concerned research domain. According to Kripke *et al.*[128], short sleep lengths are associated with decreased life expectancy. Tepas and Carvalhais[129] reported that permanent night-shift workers sleep longer on their days off, but they still sleep almost 4 h less per week than the day workers do. Similar results have been reported in plenty[75,121,129–134]. Dahlgren[130] has found that sleep length reduces to 4.5 h on the first night shift, but increases again over six consecutive night shifts to reach a level of 5.7 h. Several workers have also reported decreased sleep length during morning and night shifts than all other workdays and days off[57,122]. Further, it has been documented that workers on the afternoon/evening shifts sleep the longest, workers on the day shift sleep slightly less and night-shift workers sleep the least[25,129,135–138]. Workers exposed to *on call shift work* have also shorter sleeping time[139]. Studies from several laboratories have shown that sleep duration is dependent on the time of sleep onset[89,90,140]. Sleep duration has been found to be the shortest among shift workers if it is started some hours after the circadian trough in activity/body temperature (?) rhythm, whereas sleep started close to the trough is somewhat longer[141]. This conclusion is also supported by field studies, showing that sleep duration decreases when sleep onset is delayed after the night shift[142]. Sleep on morning shift days can also be shortened, especially if work starts early in the morning[143]. Reduction in sleep length is associated with decrements in performance[76,124,144–146], decreased alertness[147] and higher incidence of accidents and increased probability of precipitation of health problems among/by night workers[29,75]. Changes in mood state, increased feelings of fatigue, sleepiness and irritability, inability to concentrate and periods of misperception also occur on account of reductions in sleep length in night-shift workers[129,135–138].

In many studies it has been demonstrated that rotational shift workers report more fatigue than do day workers[76,83,148]. Usually, fatigue is particularly widespread during the night shift, hardly appears during the afternoon shift and is intermediate during morning shift[55]. Kecklund *et al.*[109] suggested that morning shifts (starting between 04.00 and 07.00 h) are usually perceived as extremely fatigue-inducing. Rosa and Colligan[149] demonstrated that the 12-h night shift produces higher ratings of fatigue than 8-h night shifts.

Sleep as a function of age

A positive correlation between the magnitude of sleep problems and age is a natural phenomenon[150–152]. These authors reported that greater the age, poorer was the sleep quality. Humans at the age of 50 years and above tend to use hypnotics frequently to get rid of their sleep problems[150]. The problems of sleep are usually magnified if a aged human happens to be a shift worker[25,26,37,151,153–155]. According to Marquie *et al.*[151], sleep quality becomes poorer in shift workers at 32 and 42 years of age. Furthermore, reduction in sleep length was associated with increasing age for workers on afternoon and night shifts, and increasing sleep length for workers on a morning shift[25]. Pavard *et al.*[156] documented that sleep length may decline with age and the rate of decline has been shown to be the largest among the night workers. Middle-aged shift workers have been shown to experience more superficial sleep[157]. There are a number of papers that substantiate the cause of the poor adjustment of the older shift workers to shift work to the greater amount of sleep disturbances[24–26,28].

Sleep as a function of sex

Female shift workers have been reported to experience more sleep disturbances than men. They suffer from drowsiness more frequently during work[158]. The problems of drowsiness become severe when they work in the morning shift[159]. Sleep length was reported to be shorter in case of female night-shift workers. The added responsibilities of looking after the home and children may aggravate sleep problems and tiredness in female shift workers, thus adversely affecting their health[29,160,161]. In addition, female shift workers had higher complaint rates at every age[151].

Psychosocial/psychophysiological problems

The shift workers have been shown to experience a number of psychological disturbances and family dysfunctions, as a result of which there is a serious impact on the family and social life[113,115,162–165]. The irregular work hours affect the whole family: the worker, his/her spouse and children. The displacement of the shift worker in time and space can result in domestic inconvenience, both for the individual and spouse as well as other members of the family, to the extent that it could have detrimental effects on family relationships[166]. The difficulties in social life are mainly due to an inharmonious relationship between work schedules of shift workers and those of other day workers. Thus it is difficult for shift workers to participate in regular meetings and in other social events/activities, which are usually scheduled in the evening or on weekends[162,167].

It has been documented that various psychosomatic and psychoneurotic complaints are more common among shift workers[24,159,165]. However, there is no evidence that shift work is related to manifestation of psychiatric ailments. Shift workers also complain more frequently about depression, helplessness and stress. Healy and Williams[168] and Healy *et al.*[169] proposed that the psychosocial disruptions leading to depression may produce a state of circadian disrhythmia and consequently may lead to helplessness-type of cognition as a result of disturbances in neurovegetative functions. Many studies have found a relationship between shift work and anxiety, and between shift work and depression. In a group of male textile workers, Costa *et al.*[170] found that 72% of workers who gave up permanent night work did so as a result of neurotic troubles. In addition, neurotic disorders were more than five times more likely to occur in three-shift workers, and more than 16 times more likely to occur in permanent night workers than in day workers. There are also common core complaints in shift work and depression such as disturbed sleep, disturbed appetite, lethargy, apathy, poor concentration and neuroticism[171]. Thus, it seems clear that the depression-induced psychosocial dislocations bring about dysrhythmia[172,173].

An important relationship has been detected between night-shift dose (the actual number of remunerated night shifts) and psychosocial stress[174]. Taking into account the worker's well-being and health, the result suggests that psychosocial and environmental stress factors at work act independently from shift-related stress factors. He also found a moderate correlation between night-shift dose and other variables such as stress at work, job satisfaction and unspecific complaints. According to Freese and Semmer[175], stress at work is an important predictor of ill health, independent of shift work. They argue that the impact of stress at work (working conditions) other than shift work itself, on ill health, deserves greater concern. Kandolin[176] reported that female nurses in three-shift work experience more stress symptoms and often this leads to less enjoyment in their work than women in two-shift work. Male nurses reportedly have the same amount of burnout and stress in both two- and three-shift work. It has also been noted that the early start of the shift puts the nurses under considerable stress[177].

Of the mental health, it has been recently reported that one-shift workers enjoy more degree of positive mental health than the two- and three-shift workers. Further, positive mental health is better in two-shift workers than three-shift workers[178]. However, Kumar[178] did not specify the timings of various shifts and probably ignored the fact that subjects involved in his study are rotational shift workers. Now the question arises: does the mental health status keep on oscillating as the shift workers move from one shift to another at weekly intervals? This perhaps seems unlikely and Kumar's work needs to be reinterpreted. Also, positive mood ratings have been noted to be the lowest and negative mood ratings the highest on the night shift in firefighters and that the opposite is true for the afternoon/evening shift[103]. Of the profile on mood states, the scores for depression and fatigue have been found to be significantly higher after a night on call[179]. Similarly, a decline in reaction time and a deleterious change in mood scales have been reported after a night of emergency admission call[180,181].

A recent study conducted by our laboratory examined the effects of three-shift work schedules of shift workers on anxiety and mental health of their day-active spouses and children. The levels of anxiety were found to be significantly higher in spouses and children of shift workers compared to their counterparts sampled in the family of day workers. Also the status of mental health was significantly low among spouses of shift workers compared to their day-working counterparts[182]. This indicates that disturbed daily schedules of shift workers may modulate anxiety and mental health in their spouses and children.

A model proposed by Rutenfranz *et al.*[135] suggests that the major disease mechanism is brought about by disturbed circadian rhythmicity, which leads to stress. The stress reaction is responsible for complaints such as lack of well-being and probably adverse health states. The intervening variables such as housing standards, sleeping conditions, the family situation, personality and psychological adaptability are also responsible for such complaints. These intervening factors determine whether a particular person is able to cope with shift work successfully[94]. Social environment may also play a key role in an independent pathway, from shift work to disease[183,184].

Chan[161] has reported that about 20% of those who start shift work eventually find it difficult to continue because of social rather than medical reasons. Workers exposed to on-call shift work have also disturbed psychological equilibrium and family and social life[139]. Åkerstedt[113] indicated that shift work that involves night shifts strongly influences the psychology and psychophysiology of the individual.

Socially, the individual's opportunities are restricted from full participation in the social activities, which are designed mostly for daytime workers. Aschoff *et al.*[185]

have documented that social cues are of primary importance for retention of circadian rhythms. Giedke *et al.*[186] have also suggested that the social zeitgebers are capable of sustaining human circadian rhythms. According to Barton *et al.*[187] the change from a delaying to an advancing system results in an increase in sleep difficulties, but a decrease in social disruption. The decrease in social disruption has been thought to result from the specific sequence of the shifts and the discontinuous nature of the shift system, particularly the long weekend off every third week.

The study conducted by Costa *et al.*[188] indicates that the characteristics of flexibility of sleeping habits, ability to overcome drowsiness and lower manifest anxiety, are associated with better tolerance to shift work.

The first ever study of shift work which included a participation of nurses for various variables like altered neurovegetative function, perceived criticism from others, sense of purpose and control, and psychosomatic complaints, has exhibited a marked change in all these variables. Subsequently these findings may have implications for circadian rhythm hypothesis of depression and also for a methodology for future studies on psychosocial variables in depression[169]. In contrast, Skipper *et al.*[19] have suggested that shift work is not significantly related to the nurses' physical health and mental depression.

Clinical problems

It is well known that humans sleep during the night and remain awake and active during the day. Therefore, human mind and body have not been evolved to cope with the burden of shift work at night or in any other unsuitable or uncomplimentary work schedule. Shift work can lead to a host of problems attributed to the disturbances of the circadian system in some people. Health problems due to shift work can broadly be classified as: disturbances of sleep, impaired physical and psychological health, and disturbed social and domestic life. Rotational shift work in general and shift work during night in particular have been proposed to be detrimental for human health by way of temporal dysfunction of human biological clock. The interaction between internal desynchronization, tolerance to shift work and some psychiatric problems (e.g. affective disorders) should be considered with regard to interindividual differences. In fact, some symptoms of intolerance (e.g. persistent fatigue, sleep disturbances, alteration of mood) may also be found in affective disorders. Despite the fact that affective disorders and intolerance to shift work differ with regard to their respective clinical features, evolution, treatment and prognosis, it could well be that the role played by circadian rhythm alterations has some similarities in both diseases. Nontolerant shift workers and patients with affective disorders might be sensitive to internal desynchronization[22,189]. According to several authors, the circadian physiological rhythms of shift workers seldom adjust completely to the night shift[11,93,99,190–193]. The phenomenon of aging has been found to aggravate the adverse health effects of shift work, the critical age being on an average 40–50 years[24–26,28]. Deterioration in health has also been noticed after many years of shift work in some shift workers[170,194,195]. Koller[196] has distinguished shift workers from day workers in that the health problems appeared earlier among the former than among the latter. In addition, our studies reported that older shift workers tend to exhibit statistically significant lower peak expiratory flow rate (one of the important measures of the pulmonary functions) compared to diurnal workers[197,198].

Cardiovascular complications

In industrialized countries, one of the most common causes of death is cardiovascular disease (CVD). Several studies have reported circadian periodicity in myocardial infarctions[199–202], angina pectoris[203] and sudden cardiac death[204] with a peak in the morning hours. A secondary peak in the late-evening hours has also been observed by these authors. These findings provide some support for the hypothesis that a rhythmic increase in coronary tone or coronary spasm that occurs in the morning could be responsible for the increased incidence of acute symptoms of coronary heart disease (CHD)[202].

Knutsson[2] found a higher risk of CVD among shift workers compared to day workers. Similar findings have been documented in many other studies[120,161,165,205–209].

Koller *et al.*[24] carried out a cross-sectional study of a sample of the employees at an Austrian oil refinery and they have reported a higher prevalence of cardiovascular symptoms and complaints among the shift workers. The morbidity for disease of the circulatory system has been reported to be 20% in shift workers, 7% in day workers and 15% in ex-shift workers. The difference has been shown to be statistically significant between shift workers and day workers. Similarly, Angersbach *et al.*[194] have found a slight but nonsignificant excess of CVD morbidity among shift workers. The incidence has been noticed to be 14.8% for the day workers and 16.8% for the shift workers.

Koller[196] has reported a dose–response relation between years of shift work and CVD in oil-refinery workers. Results obtained by Knutsson *et al.*[210] indicated that shift work is associated with increased risk of ischemic heart disease (IHD), at least during the first two decades of shift working. The association is independent of age and smoking habits. The relative risk of IHD has been noticed to fall sharply after twenty years of shift work. In case of female shift workers, exposure to 6 or more years of shift work may increase the risk of CHD[211].

There are several factors that may increase the risk of developing CVD. The major risk factors are: smoking, hypertension and high blood cholesterol. Knutsson and

Zamore[212] and Koller *et al.*[24] have demonstrated an increased prevalence of risk factors for CHD in shift workers. Similarly, an association has been witnessed between hypertension and shift work[212,213]. However, on the contrary, results of several studies do not indicate that high blood pressure is more common among shift workers[2,214].

Several studies demonstrated that smoking habit seems to be more common among shift workers than among day workers[2,194,212,214,215]. One possible explanation for this smoking behaviour may be that a predilection for a smoke is influenced by the working hours, perhaps as a stimulant or as a way to spend time during the night shift. Shift schedules may also influence the smoking behaviour and the latter makes a shift worker more prone to cardiac complications[138]. One has to keep in mind that smoking habits may be related to the type of work and industry. A boring task (e.g. mail sorting, watching a computer monitor with 'nothing' to do) may favour smoking, while in high-risk industries (e.g. oil refinery) smoking is strictly forbidden. Therefore, findings and comments about habits of shift workers cannot be generalized.

The cholesterol level has been witnessed to be higher in shift workers compared to day workers[216]. De Backer *et al.*[217] found that workers with the most irregular working hours may tend to have significantly higher total cholesterol. Knutsson[2] has also found higher total cholesterol levels in shift workers than day workers, but the differences seem to be small and statistically insignificant. Furthermore, high serum triglyceride levels have been shown to be more prevalent among the shift workers than the day workers[2,212,214,216,218,219]. Several authors have concluded that the level of serum triglyceride is a risk factor for coronary artery disease[220–222]. Also, it has been found that rotating shift workers have abnormally elevated norepinephrine levels which if not controlled, may lead to higher cardiovascular risks[223].

Lennernäs *et al.*[224] documented that dietary intake is lower during night shifts than during morning and afternoon shifts. According to them, the redistribution of food intake from diurnal eating to nocturnal eating is related to serum total cholesterol, LDL cholesterol and HDL cholesterol, which might increase the risk for CVD. Even if the dietary intake and quality are similar in day workers as well as shift workers, there are still differences in eating habits that might contribute to differences in levels of serum lipids[219,225]. This makes night workers vulnerable to CVD[2,209]. Fujiwara *et al.*[226] found that sleep factors, namely the onset of sleep and/or the total sleep length seem to be more potent in modifying the circadian rhythm of serum cortisol, specially in night-shift workers. It has been documented that circadian rhythms in serum cortisol and urinary-free adrenaline disappear in workers while on night shift[226].

Most of the studies discussed above show some relation of CVD with shift work. This means that the harmful effects of shift work on health have to be regarded as more serious than has previously been thought.

Gastrointestinal complications

It is well known that the dietary intake is of immense importance to nutritional status and health[227,228]. In addition to a balanced intake, the time of the day for consumption and the frequency of intake may also be equally important. In fact, the time of the day for consumption may affect uptake, digestion and metabolism depending on the phase of the individual's circadian rhythms[229–232]. Meal timing is considered as an important socio-environmental synchronizer of the circadian rhythms and influences human metabolism. Further, the temporal distribution of food intake has also an influence on human performance[233,234].

Rotating shift work has well-known harmful effects on human health and well-being. It disturbs sleep, wakefulness, eating patterns and social life and in the long run, often results in gastrointestinal diseases. Several authors have documented an association between shift work and gastrointestinal disorders[54,67,165,170,235–237]. This association may be mediated by many factors. One may be the irregular eating habits of shift workers, since there are some indications that the temporal distributions of food intake as well as the qualitative and quantitative food intake may affect health[232,238–242]. It can be argued that the gastrointestinal disturbances result from eating food at the *wrong* time, with abnormal patterns of gut motility and gastric acid secretion being likely[238,241,243,244]. No doubt this is a factor, but other possibilities include: the lack of hot food at night and so the reliance upon sandwiches, etc.; the tendency to nibble rather than take full meals; the higher intake of carbohydrate, caffeine and alcohol; and the higher consumption of tobacco. All of these changes have been observed in night workers and might play some role in increasing the prevalence of gastrointestinal disorders[245]. Gastrointestinal complaints of gastric upset, disturbed appetite, gas, constipation, diarrhoea, poor eating, dyspepsia, epigastric pain, gastroduodenitis, peptic ulcer etc. are strongly correlated with shift work in a number of studies[21,67,111,159,161,170,208,246–248]. The reported poor *eating satisfaction* in shift workers[249], probably reflects irregular meal times rather than malnutrition. However, there are contradictory reports suggesting no links between shift work, eating habits and associated complications[250–253].

Shift work causes a prominent change in the pattern of secretion of gastrin/acidopepsin[254]. This may be one of the causes of frequent occurrence of peptic ulcer disease in night workers than in day workers. An earlier occurrence of gastrointestinal disease has also been reported among rotating shift workers than among day workers[194].

Nocturnal eating in connection with night work might have negative consequences in terms of metabolism due to circadian rhythm factors[224,230–232,239,255,256]. Thus frequent night eating may be related to undesirable metabolic effects, for example, increased levels of serum lipids or an increased body mass index in shift workers.

Armstrong[239] speculated that an early night meal and early morning meal might disturb the overall circadian rhythmicity of the anabolic and catabolic processes, which maintain constant phase relationship with the cycle of sleep wakefulness. This phenomenon might, in turn, cause an imbalance in the endocrine rhythms associated with fat metabolism. Shift work unequivocally upsets the temporal distribution of meal timings, which in turn may act unfavourably both on the digestion and the psychophysiological conditions[163,194,257]. Meal timings have also been known to act as powerful synchronizers of circadian rhythms in various physiological functions.

According to Costa *et al.*[188] subjects with digestive disorders (gastroduodenitis, peptic ulcer) show a greater phase shift and a reduction of the amplitude on night work, suggesting a possible relationship between the short-term circadian adjustment and the long-term tolerance to shift work.

Non-clinical problems

Performance

Global performance decrement is one of the harmful effects of shift work. In industries and factories, performance variables are of immense importance, because they are related both to productivity and safety. The worker's inability to adapt to the shift work schedule can lead to a loss of physical and psychological well-being and can produce negative safety and performance consequences. Studies conducted in various laboratories demonstrated that performance deteriorates during the night time[12,76,77,121,131,258].

A number of studies demonstrate the presence of circadian rhythm in the performance variables[10,32,59,92,259]. However, the characteristics of circadian rhythm in performance depend upon the nature of the task being performed[12,260]. A circadian rhythm of performance in maximal speed of tapping and time estimation of 10 s has been demonstrated[59]. According to Tilley *et al.*[121], night shift work is associated with reduced reaction time and poor mental arithmetic on the night shift. A higher error rate in performing addition problems and fewer signal detections during the night shifts have been demonstrated by Tepas *et al.*[131]. Bjerner *et al.*[261] reported that error in meter-reading over a period of 20 years in a glasswork has been shown to have a pronounced peak during the night shift. A secondary peak has also been reported during the afternoon shift. Browne[262] showed that performance declines in telephone operators on night shift. Similarly, Hildebrandt *et al.*[263] found that locomotive engineers fail to operate their alerting safety device more often at night than during the day, with a secondary peak around 15.00 h. A recent study on air-traffic controllers reveals that the performance impairment was significantly higher at the end of an 8-h midnight shift than an 8-h day or evening shift[155]. Further, they emphasized that performance deterioration was similar for 8-h midnight shift and 12-h day or evening shift. It has been reported that shift workers take longer time than their day-working counterparts to perform finger counting and random number addition[32,56]. Further, some authors have found a lower accident rate and a higher performance rating in permanent night workers compared with the rotators[102,264–266].

Poor sleep quantity (sleep deprivation) and quality have been considered as the key factors in modulating the performance of shift workers during the night shift[24,119,120,267,268]. Furthermore, in shift workers sleep deprivation and desynchronization of biologic rhythms lead to impaired physical performances[9,165]. Performance decrement has been reported in nurses during the night shift, although there has been *no sleep deprivation* in a study conducted by our group[55]. Thus the results negate the hypothesis that implicates sleep deprivation or sleep debt as one of the major reasons for performance decrement[55,259]. Could it be that sleep during the habitual timing, but not the length of sleep is imperative for normal human performance?

The circadian rhythm and sleep–wake cycle are mainly related to the psychophysiology of shift work. People in either rotating shifts or in a static/shift system have to work during the night at the low phase of their circadian rhythm. On retiring to bed, although they fall asleep rapidly, they are prematurely awoken due to the high phase of their circadian rhythm. This leads to severe sleepiness and reduced performance[113]. The results of studies conducted by Gupta[259] and Gupta and Pati[56] indicate that the shift rotation pattern is also important for normal performance. Studies on performance of shift workers working in three different types of rotational patterns revealed that 12-h night shift system for 15 consecutive days was the worst compared to the other two shift patterns, i.e. 12-h night shift for 1 week and 8-h rotational shift system[56,259].

In summary, the level of work performance efficiency on a night shift depends primarily upon several factors, namely the demands of the task; the type of shift system and hence potential for both short- and long-term adjustment; individual differences between shift workers in the degree to which their rhythms adjust to night work; and sleep deprivation[52,56,269,270].

On-duty injuries and/or accidents

Several studies have documented that accidents and injuries are imputed to sleep deprivation and disruption that occur on account of shift work[165,208,271].

A number of studies have demonstrated that the rate of serious accidents is higher at night (Table 1) than during the day[12,86,120,259,272–274]. Furthermore, it has been observed that despite considerable reduced traffic during night, single-vehicle accidents occur past-midnight at a significantly higher rate[275–277]. Studies conducted on train drivers also revealed that they tend to overlook and/or issue more warning signals during the night shift. Various kinds of industrial injuries have also been shown to be two to three times higher during the night shift compared to the evening shift[18,278–282].

The accidents resulting in injury are more frequent in machine-paced workers at night[283]. It seems likely that the higher rate of injuries at night necessarily reflects upon the individual's circadian rhythm in performance capabilities and alertness that in all probability failed to adjust sufficiently to the night shift[269,283]. Several authors have also found that the rate of accidents increases across 4–5 consecutive night shifts due to inadequate circadian adjustment, an accumulation of sleep deficits[284,285] and social factors[286].

Most of the available accident data on night shift have been obtained in the transport area. Most of these accidents are thought to be due to sleepiness associated with lack of alertness. With respect to air accidents, Ribak *et al.*[287] found that military air mishaps mostly occur in the early morning. Fatigue on account of improper work scheduling appears to be one of the most important causes of civil air transport accidents[288]. A number of spectacular nuclear accidents have been partly attributed to fatigue-inducing work schedules[271]. Some studies indicate that the number of injuries increases as the clock-hour progresses[280,282]. Wojtczak-Jaroszowa and Jarosz[289] went further to suggest that factors such as increased activity or density of the workers may be of greater importance in the occurrence of an occupational injury.

Bhopal is presumably the first 'chronotoxic' industrial disaster[290]. Another important point is that before the Bhopal and Chernobyl disasters, circadian risk of accidents were considered from an individual point of view. After the disasters the question arises: how to prevent population disasters with high-risk industries (e.g. nuclear power plant, oil refinery). The peak time of risk at night involves not only a few night workers, but the population dwelling around the plant.

Table 1. Time of occurrence of some major industrial accidents

Accident	Time
Bhopal gas tragedy	00.56 h
Chernobyl nuclear disaster	01.23 h
Three-mile Island incident	04.00 h
Rhine chemical spillage	Early morning
Gaisal train disaster	01.15 h

Shift work and personality

There are two identified species of people in this world: *Homo larkensis* (better known as the lark people or the morning types) and *Homo owlensis* (also referred to as the owl people or the evening types)[291]. These are called the chronotypes and are identified in the local population by their peak phase of body temperature. Some workers have also designed specific inventories for identification of different chronotypes in the population[82,292].

In this context circadian rhythm in body temperature assumes significance, specially because it has been considered as a marker rhythm for several other rhythmic functions in humans[14,37,65,293]. The body temperature rhythm has also been shown to vary as a function of morningness and eveningness. According to the time of going to bed and awakening time, the owl people go to bed almost past midnight, while the lark types go to sleep around 22.00 h or even earlier than this. In contrast, as the day proceeds a subtle change slowly becomes evident in both species. The lark people show signs of fatigue first. Alert and sharp in the morning, they begin to slow down and ease up as sunset approaches. The owl persons on the other hand have a long way to go still.

According to Minors and Waterhouse[41], the metabolic effects of eating during different times of the day might also be related to the chronotype. Individual differences, for example being morning active or evening active type, can explain some of the variations in adaptability to shift work[294]. Evening types appear to experience fewer problems in adapting to night work[82,295]. According to Åkerstedt[113] older age and morningness personality are related to higher than average problems in adjusting to shift work. Breithaupt *et al.*[296] observed that it is predominantly morning types who react to late shift work with sleep deficiency and its accompanying pathological symptoms. According to them, it is not that morning types have a less-efficient adaptive capacity than evening types, but rather the evening types have a constitution which is inherently less vulnerable to delayed sleep, simply because of their delayed circadian phase position[296].

A population study conducted earlier on 582 subjects, representing the human population living in hot and dry tropical climatic conditions revealed that 75, 16 and 9% have been found to be morning active, evening active and intermediate type individuals, respectively[292] (Figure 13). These observations differ from the Gaussian distribution (10% MT, 10% ET and 80% either type) that is found in temperate climate, as shown by Horn and Ostberg[297] and Ashkenazi *et al.*[298]. It may be unsafe to generalize a 'local' finding from a European country to the entire world. The acrophase timing of oral temperature rhythm in evening-active individuals of the tropical population has been located in the late evening hours (around 19.4 ± 0.55 h). In contrast, it has been observed that the morning-active individuals have their peak at about 4.9 h earlier (14.5 ± 0.85 h) than their evening-active counterparts[292] (Figure 14). It has also been witnessed that the morning-active subjects remain at their best between 8.6 and 10.7 h with reference to the performance variable (e.g. random number addition speed), whereas evening-active subjects remain at their best between 16.9 and 20.2 h, approximately six hours later (Figure 15).

Folkard[12] suggested that in situations where safety is paramount, the solutions to the problems of shift work adaptation are the creation of nocturnal sub-society that is not only always work at night, but also remain on a nocturnal routine on rest days. This seems impractical to some extent because this suggestion advocates creation of a sort of isolated world for a human sub-population of desired dimension. It is almost certain that the suggestions of Folkard[12], if implemented, would invite enumerable social and psychosocial complications. It is indeed difficult to locate any perspective subscribers for Folkard's doctrine.

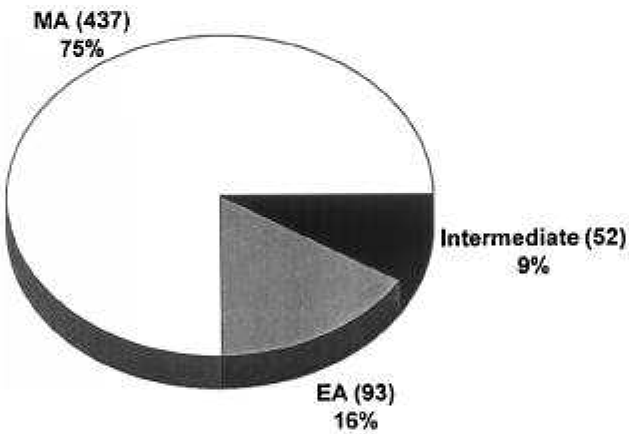

Figure 13. Frequency distribution of morningness and eveningness in a human population. Based on information taken on a questionnaire from 582 mixed inhabitants of Chhattisgarh, India, irrespective of age, sex and working habits. MA, morning active; EA, evening active (from Gupta and Pati[292]).

Shift management

As evident in the foregoing review of the studies on shift workers, it is unequivocal that shift work is linked to a series of acute and chronic effects on human beings. There is an absolute need for an optimization of human shift work. Is it possible to abandon the practice of shift work? A modern society probably cannot afford to do that. Then the question arises: how can the circadian rhythm desynchronization be minimized? Several authors have suggested counter-measures for rhythm entrainment.

Shift systems

It has been unequivocally accepted that night shift alone or as a component of the two-shift or three-shift system is the worst for diurnally-evolved humans. Is it possible to get rid of the detrimental effects of night shift system? It is possible to reduce the effects of the night shift. The first thing that comes to our mind is the speed of rotation of the system. The rotation could be either slow or fast. Several authors have examined this option. The quickly-rotating shift system seems to find maximum favour. A fast rotation helps in minimizing sleep deprivation[122], circadian rhythm disruption and improves social contacts[88,299], alertness and well-being[52,138,218]. Further, the shift workers working in rapidly-rotating shift system have been shown to perform excellently while on memory-loaded task[300]. Rapid rotation (2 to 4 days) from a chronobiological point of view is advantageous with regard to the conventional weekly rotation. This has been demonstrated experimentally in field studies involving oil

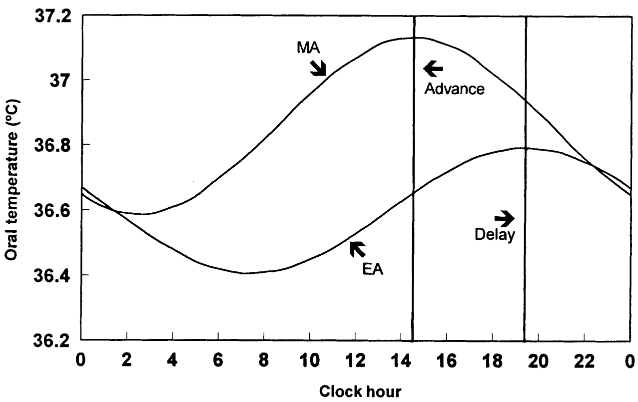

Figure 14. Illustrative example of circadian rhythm in oral temperature (°C) of a group of morning-active and evening-active subjects. $Yt_i = M + A \cos(\omega t_i + \varnothing)$ continuous curves fitted to data obtained during wakefulness span only. Oral temperature peak occurred 4.9 h earlier in MA compared to EA (from Gupta and Pati[292]).

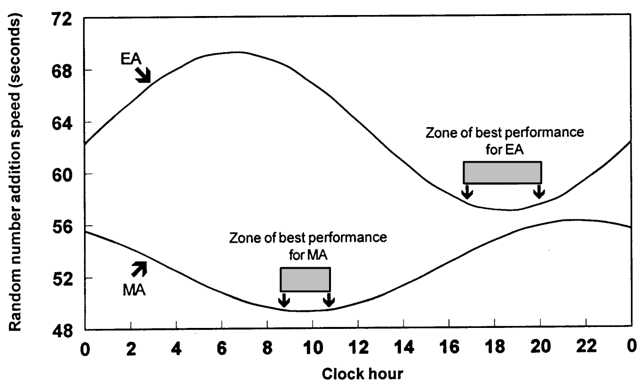

Figure 15. Illustrative example of circadian rhythm in random number addition speed (seconds) of a group of morning-active and evening-active subjects. $Yt_i = M + A \cos(\omega t_i + \varnothing)$ continuous curves fitted to data obtained during wakefulness span only. MA exhibited best performance in between 8.6 and 10.7 h whereas EA were at their best between 16.9 and 20.2 h (based on Gupta and Pati[92]).

refinery operators[301–303]: (1) The transient desynchronization of the temporal organization is smaller with the rapid rotation than with the other. (2) The desynchronization of sleep patterns (EEG recordings = hypnogram) is smaller with the rapid rotation. (3) As a result, the recovery of a physiologic temporal organization occurs more rapidly after the rapid rotation than the weekly rotation. But the rapid rotation does not solve the problem of nocturnal risk of accidents. Further, there are reports that do not support the quick rotation system. The main argument is that the extremely quick rotation would have reduced free time between shifts by several hours[134,304], leading to substantial sleep loss. Then one should find out the threshold for 'free time' between shifts that would not cause loss of sleep. However, there is no such study to support the above. Nevertheless, quickly-rotating shift system appears to be better now.

Direction of rotation

Another important factor that deserves attention is the direction of the rotation of shift schedules. The direction of rotation may be either clockwise (forward rotation or delaying system) or counter-clockwise (backward rotation or advancing system). Several authors have taken keen interest to examine the role of this factor in shift optimization. The clockwise rotation was noticed to be better tolerated by the shift workers than the one that follows the counter-clockwise pattern. A change from counter-clockwise to clockwise rotation has been documented to improve production, well-being[70,218], sleep quality[305,306] and reduce physical, social and psychological problems[307]. Although there are limited evidences, theoretically clockwise rotation of work schedule (i.e. morning–evening–night) seems to be the best universal pattern. The findings from jet-lag research that the westward travel produces quicker resynchronization of human circadian rhythms compared to the eastward travel, support the above conjecture.

A recent study conducted in our laboratory shows that desynchronized circadian rhythms in shift workers returned to normal when they were allowed to behave as day workers with nocturnal sleep[33]. Figure 16 shows illustrative examples of spectral analysis that clearly support the above conclusion. Results indicate that in the 1st spell of study several variables, namely skin temperature, heart rate and peak expiratory flow rate had non-24 h periods. However, in the 2nd spell after about 16 months all variables exhibited circadian periodicity ($\tau = 24$ h) when the shift workers had the opportunity to have 'on-job' nocturnal sleep. These results support the findings reported by Reinberg *et al.*[14] that when a shift worker with poor tolerance was transferred from shift work to diurnal work, the desynchronized rhythm in oral temperature became resynchronized after about 1 year, exhibiting prominent period equal to 24 h in oral temperature rhythm (Figure 17). In our study this transfer was achieved accidentally following an irregular but frequent shut down of the cement factory.

Several authors have studied the effects of nap on alertness, performance and sleep quality[308–311]. Brief naps during work may be helpful to some workers as they enhance alertness temporarily. It has been shown that short naps of 20–40 min can be beneficial as they may improve sleep quality, performance and mood[308–310]. In some cultures, particularly in Japan, night-shift naps are officially sanctioned[312]. In some European countries, afternoon naps are officially permitted.

Furthermore, studies on the effects of simulated night work demonstrate that exposure to bright light during night can virtually eliminate circadian maladjustment among night workers[313]. After four cycles of light treatment the endogenous circadian rhythms of body temperature, subjective alertness, cognitive performance, urine production and plasma cortisol secretion have been observed to be completely adjusted to the new schedule[104]. In addition, exposure to bright light during the night shift has been reported to improve daytime sleep compared to controls[94,192]. NASA scientists have implemented this principle for the first time in a manned space flight[314]. NASA is now regularly using the bright-light technology (therapy) on all space shuttle missions[104]. Lithium[315–317] and to a certain extent other antidepressant drugs[318–320], used to control depression and manic-depressive illness, have been shown to act on the period of certain circadian rhythms. The latest drug being used as a rhythm entrainer is melatonin. Its potential use in circadian-rhythm disorders has been investigated in field

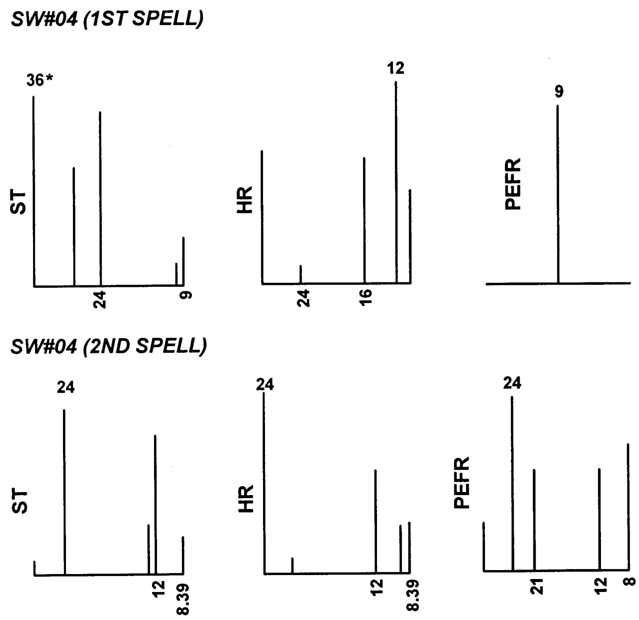

Figure 16. Illustrative examples showing power spectra of three variables (ST, skin temperature; HR, heart rate; PEFR, peak expiratory flow rate) in a shift worker (SW #04) in two spells of studies. *Period (τ) (from Chandrawanshi and Pati[33]).

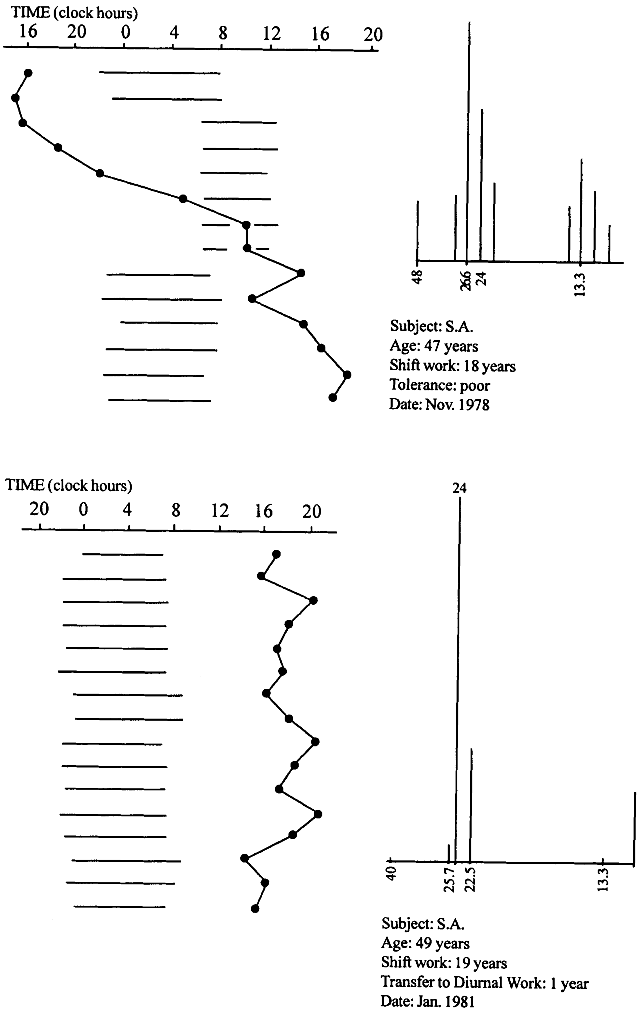

Figure 17. Desynchronization of the oral temperature circadian rhythm of subject S.A. with poor tolerance to shift work. (Left) Horizontal bars represent both duration and location of rest (lights-off to lights-on) governed by shift schedules (rapid rotation); black dots and solid lines represent day-by-day acrophase (∅) location (peak time) of the temperature rhythm. (Right) Power spectrum of the temperature rhythm with period τ in hours. (Upper panel) Prominent line for $\tau = 26.6$ h. (Lower panel) 24-h synchronized rhythm of subject S.A. about 1 year after his transfer to diurnal work (from Reinberg *et al.*[14]).

studies of jet lag and shift work and in simulated phase shifts[58,321–323].

Recommendations

On the basis of studies done by our group and others, it is recommended that in every work place where shift work is mandatory, a chronoclinic should be established. Trained healthcare-personnel of the chronoclinic should monitor intermittently (preferably every alternate year) the state of the biological clock (synchronized or desynchronized?) of each shift worker. Upon discovering rhythm desynchronization his/her transfer from shift work to day work for at least one year should be recommended to the employer/management. This would perhaps rule out the possibilities of ill-effects of shift work that are expected to be impinged upon the workers. It has been proposed that while examining tolerance/intolerance of a shift worker to rotational shift work, the levels of anxiety and mental health status of the individual under scrutiny should be taken into consideration. Sleep–wake disorder is another important variable that cannot be simply ignored while ascertaining intolerance to shift work. In addition, appropriate chronotherapy should also be administered into intolerant shift workers while they are being transferred from shift duty to day duty. A model has been proposed with a view to optimize shift work (Figure 18). This model takes into account most of the important variables that are thought to have a bearing on the effective management of shift work.

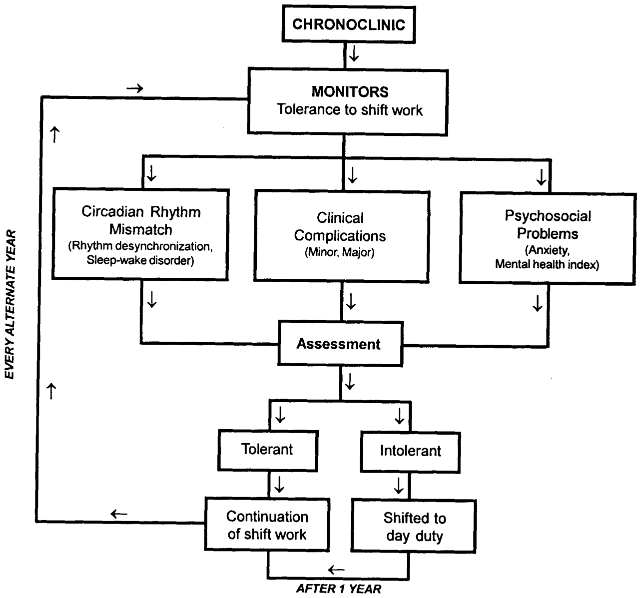

Figure 18. Model suggesting optimization of human shift work.

All these counter-measures, either individually or in combination, may improve the coping ability of shift workers thus minimizing the occupational health hazards and maximizing their performance. This would substantially increase the productivity of the organization for whom they are working.

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