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Pattern of shift rota modulates oral temperature circadian rhythm and sleep-wakefulness profiles in shift workers

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Abstract. Twenty four shift workers (8 from a steel industry and 16 from a Government hospital) participated in the study. The subjects were instructed to self-measure oral temperature, 4 6 times a day for about three weeks. Sleep quantity and quality for each subject were analysed with the help of an appropriate inventory. The data were analysed by cosinor and power spectrum methods. The frequency of circadian rhythm detection was in the order of 48% in senior nurses, 29% in steel plant workers and 14% in junior nurses. These were also complemented by the results of power spectrum analysis. Present results suggest that rhythms of subjective fatigue and subjective drowsiness are governed neither by oral temperature oscillator nor by the sleep/wake cycle oscillator. The results show that shift rotation pattern chiefly modulates the circadian time structure of shift workers. It is also suggested that the phenomenon of circadian rhythm desynchronization in oral temperature appears to be independent of per day total sleep length.

Keywords. Circadian rhythm; oral temperature; rhythm desynchronization; shift workers; sleep length; sleep quality.

1. Introduction

Today shift work has become a routine feature in industries, hospitals and many other essential sectors Shift workers very often suffer from sleep-wake disorders, and gastrointestinal problems (Harrington 1978; Rutenfranz 1982). They are also more prone to cardiovascular diseases (Moore-Ede and Richardson 1985). Several studies have documented the phenomenon of de synchronization of circadian rhythms in shift workers. Time structure of sleep rhythm in shift workers have received a lot of attention during the last two decades (Åkerstedt 1986; Barton *et al* 1994; Harrington 1994). In addition to shift work, the phenomenon of rhythm desynchronization among human beings has been attributed to an abrupt change in time zones, some forms of insomnia and depression (Dc-koninick 1991). Åkerstedt *et al* (1991) demonstrated by using electron encephalography that both morning and evening shifts interfere with sleep.

De-koninick (1991) has performed studies to assess the desynchronization consequences of the circadian phase of sleeping and waking with that of the rhythm in body temperature. Oral/core temperature circadian rhythm is extremely important specially because clinically significant circadian rhythms in other variables are usually described with respect to its phase position. The pattern of this marker rhythm and clinical complications taken together may help a great deal in determining the level of tolerance/intolerance among shift

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workers (Reinberg *et al* 1980, 1984, 1989). Therefore, this concept of categorization is meaningful specially since tolerance to shift work is related neither to subject's age, nor to the duration of shift work (Reinberg *et al* 1988; Smolensky *et al* 1985).

Desynchronization of oral temperature circadian rhythm has been rigorously demonstrated in rotating shift workers (Reinberg *et al* 1980, 1984, 1989; Gupta 1992; Gupta and Pati 1994b). It has also been reported that compared to the permanent day workers, sleep quantity and quality are poorer in rotating shift workers (Chang *et al* 1993). In all the above studies the pattern of rotating shift schedule, shiftwise changes in the oral temperature circadian rhythm, sleep quantity and quality have not been taken into consideration. Therefore, it was thought worthwhile to study the effect of different shifts on oral temperature circadian rhythm and sleep characteristics of shift workers working in three different kinds of shift rotation schedules.

2. Materials and methods

2.1 *Subjects*

Twenty four shift workers, 8 from a steel industry and 16 nurses from a nearby Government hospital participated in the study. The biometric and physiologic characteristics of these subjects are presented in table 1. On the basis of the pattern of

Table 1. Biometric and physiologic characteristics of 24 shift workers.

Subject code	Subject identification code	Sex	Age (y)	Weight (kg)	Height (cm)	BSA[a] (m^2)	Chronotype	Shift work experience (Y)
SW#01	(AP)	M	29	55	162·5	1·58	MA	8
SW#02	(SKT)	M	29	57	165	1·62	MA	6
SW#03	(AKS)	M	25	57	167·5	1·64	MA	2
SW#04	(SSUD)	M	27	60	167·5	1·68	MA	2
SW#05	(PK)	M	32	65	170	1·75	MA	10
SW#06	(SG)	M	38	70	167·5	1·79	MA	10
SW#07	(AG)	M	27	68	172·5	1·81	EA	10
SW#08	(SR)	M	26	65	172·5	1·77	MA	8
SW#09	(AP)	F	26	55	155	1·53	MA	6
SW#10	(KS)	F	25	48	152·5	1·42	MA	6
SW#11	(LK)	F	25	40	160	1·36	MA	6
SW#12	(VT)	F	27	50	155	1·47	MA	8
SW#13	(SF)	F	40	60	160	1·62	MA	20
SW#14	(MSG)	F	30	62	162·5	1·66	EA	7
SW#15	(AP)	F	29	50	157·5	1·48	MA	8
SW#16	(SD)	F	24	48	157·5	1·46	MA	4
SW#17	(RR)	F	22	47	157·5	1·44	MA	<2
SW#18	(Y)	F	24	42	147·5	1·31	MA	<2
SW#19	(CK)	F	24	50	150	1·43	MA	<2
SW#20	(SHER)	F	23	49	157·5	1·47	MA	<2
SW#21	(SN)	F	22	48	150	1·41	MA	<2
SW#22	(UA)	F	22	52	160	1·53	MA	<2
SW#23	(KR)	F	21	50	160	1·50	MA	<2
SW#24	(MUK)	F	21	48	155	1·44	MA	<2

[a]Body surface area by Du Bois's formula.
MA, Morning active; EA, evening active.

shift rota the subjects were divided into three groups, viz., (i) steel plant workers, (ii) senior nurses (4-20 years of shift work experience) and (iii) junior nurses (< 2 years of shift work experience).

2.2 *Pattern of shift rotation*

The steel plant workers worked under a 8h rotational shift system (night shift, 22:00-06:00; afternoon shift, 14:00-22:00; morning shift, 06:00-14:00). Usually shift workers experienced 32 off hours during the transition from one shift to another (figure 1).

Senior nurses worked in a shift system consisting of 12 h night shift for one week followed by a rest day and morning shift or afternoon shift or evening shift for three weeks (figure 2).

Shift system for the junior nurses consisted of 15 days of night shift alternating with a single rest day and morning or afternoon or evening shift for the remaining two weeks (figure 2). The latter three shifts were assigned to both senior and junior nurses in a random fashion. Only before one day the worker knew that she has to perform morning, or afternoon, or evening duty the next day (figure 2). The timings of evening shift partly overlapped the timings of both afternoon shift and night

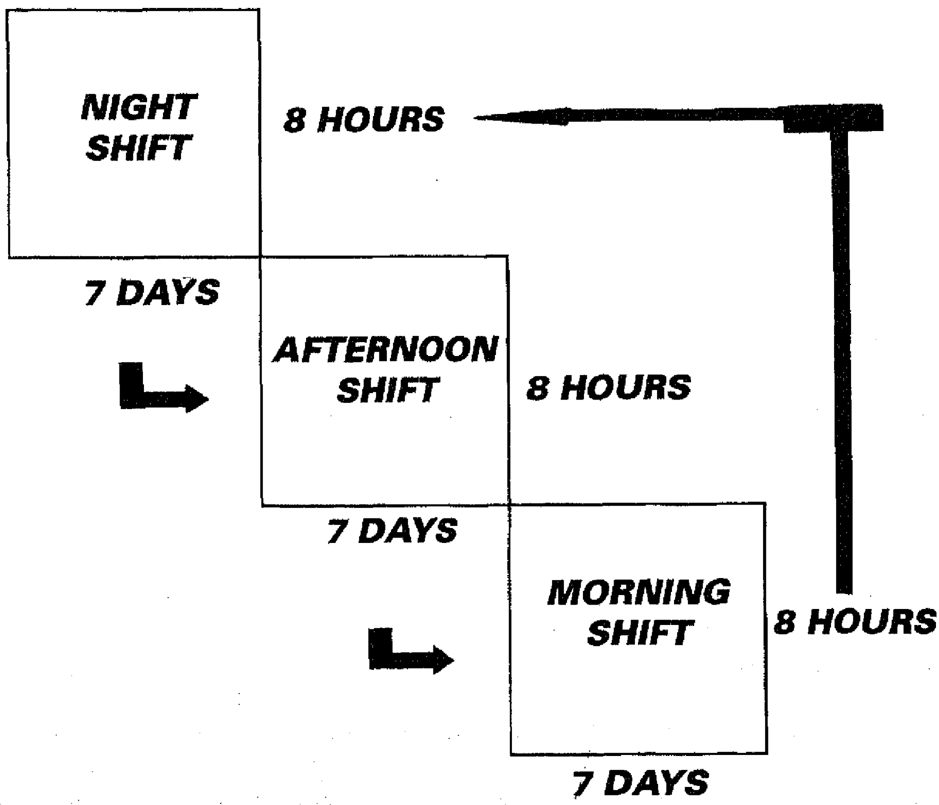

Figure 1. Rotation schedules of shift working steel plant workers. For details see § 2.2.

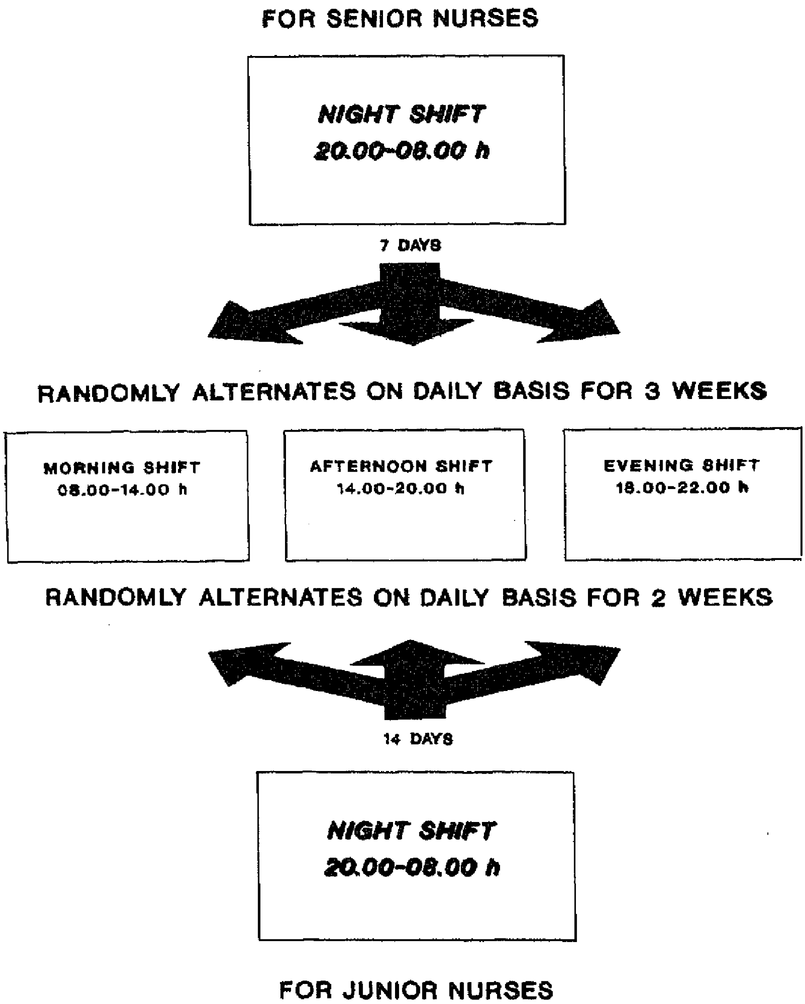

Figure 2. Rotation schedules of shift working nurses. For details see § 2.2.

shift. This was done to provide extra hands during the peak working hours of the hospital.

2.3 *End points*

The subjects volunteered for the study were instructed to self-measure oral temperature (OT), 4-6 times daily during the waking hours only over a span of twenty one consecutive days (Halberg *et al* 1972; Gupta and Pati 1994a, b). The subjects were advised to note their retiring time and awakening time daily. The sleep quality of each subject was analysed daily with the help of an appropriate inventory (Gupta 1992; Gupta and Pati 1994b). The data obtained on sleep quality and quantity from subjects working in the morning and afternoon shifts were pooled and presented as information on subjects working in other shifts.

2.4 *Statistical analysis*

Data were analysed for documenting a circadian rhythm in oral temperature by cosinor method (Nelson *et al* 1979; Gupta and Pati 1992). Various end points, viz., mesor (*M*, rhythm-adjusted mean), amplitude (*A,* half the difference between the highest and the lowest values), and acrophase (ϕ, the timing of the highest value) were computed (not presented here). Spectral analysis was also employed for detecting prominent periods in all the variables under study (De Prins *et al* 1986). This method is suitable for time series with missing data as well as for data collected with unequal time intervals (Motohashi *et al* 1987). Other conventional statistical tests were also performed wherever required.

3. Results

3.1 *Period*

Results of power spectrum analysis of time series for oral temperature show that the frequency of detection of non-circadian period (neither τ = 24 h nor τ = 12 h), was maximum among the junior nurses (67%), moderate among the steel plant workers (42%) and least among the senior nurses (26%) (table 2). The occurrence of circadian periods in the OT rhythm was maximum among the senior nurses and steel plant workers (47% for both) and least among the junior nurses (20%). When the results were analysed shiftwise it was observed that the maximum frequency of circadian periods for OT rhythm was obtained during the morning shift of the steel plant workers (60%). The lowest was in case of junior nurses (17%). The frequency multiplication of the circadian

Table 2. Frequency (%) of prominent circadian periods* for oral temperature in shift workers during different shifts.

		Frequency			
		Shifts			
Group	Period	Night	Afternoon	Morning	Total
SP	24	50	33	60	47
	12	12·5	17	0	11
	≠ 12/24	13·5	50	40	42
SSN	24	50	33·33	50	47·33
	12	25	33·34	25	26·33
	≠ 12/24	25	33·33	25	26·33
JSN	24	33	0	17	20
	12	0	33	17	13
	≠ 12/24	67	67	66	67
Pooled	24	45	25	42	40
	12	14	25	16	17
	≠ 12/24	41	50	42	43

*By power spectrum analysis. SP, Steel plant workers; SSN, senior shift working nurses; JSN, junior shift working nurses.

period was maximum in both senior and junior nurses (33%) during the afternoon shift (table 2).

3.2 *Rhythm detection*

Results of cosinor analysis show that the frequency of the occurrence of circadian rhythm was very low in case of junior workers (20%). Statistically significant circadian rhythm was documented only in two out of six nurses.

In steel plant workers significant circadian rhythm was obtained only in 3 3 % cases. In SW# 04,07 and 08 circadian rhythm was documented during the afternoon shift. In SW# 07 circadian rhythm was validated during the morning shift also.

The frequency of occurrence of significant circadian rhythm was maximum in senior nurses (58%). Of the eight senior nurses five showed a significant circadian rhythm during the morning shift and four exhibited during the night shift. In two out of three senior nurses a significant circadian rhythm was validated during the afternoon shift (figure 3).

In only four shift workers (SW # 07, 08, 09, 14) the non-circadian component was not at all demonstrable in any one of the shifts.

3.3 *Sleep quantity and quality*

3.3a *Sleep length:* Night shift data on sleep parameters were available for 21 subjects. Total sleep length was calculated as the sleep per day including the day time sleep and 'on job sleep', if available (table 3). Only nurses had the opportunity to have some hours of sleep during the night shift.

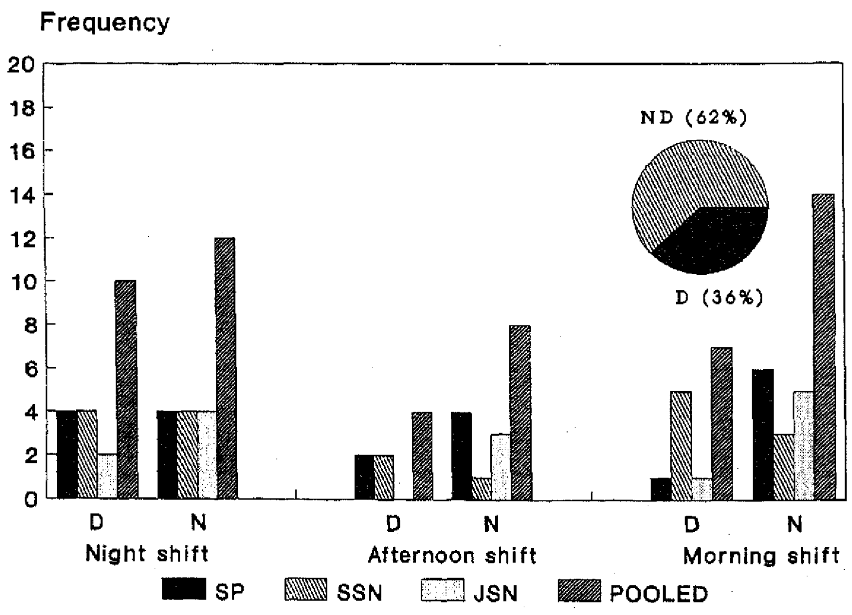

Figure 3. Frequency of circadian rhythm detection in shift workers during different shifts. The data of all the eight subjects in each group has been pooled (D, detection; N, non detection; SP, steel plant workers; SSN, senior shift working nurses; JSN, junior shift working nurses).

Table 3. Average sleep length (h) of 24 shift workers.

Subject code	Shift	Sleep length (h ± 1 SE)	Subject code	Sleep length (h ± 1 SE)	Subject code	Sleep length (h ± 1 SE)
SW#01	Night	6·44 ± 1·26	SW#09	8·12 ± 0·43	SW#18	4·39 ± 0·34
	Day	6·48 ± 0·25		8·23 ± 0·23		4·00 ± 0·00
SW#02	Night	7·25 ± 0·53	SW#10	7·57 ± 0·32	SW#19	7·90 ± 0·21
	Day	6·94 ± 0·32		6·54 ± 0·29		7·50 ± 0·19
SW#03	Night	4·71 ± 1·02	SW#11	8·92 ± 0·27	SW#20	4·10 ± 0·38
	Day	8·43 ± 0·43		9·12 ± 0·33		4·50 ± 0·20
SW#04	Night	5·87 ± 0·31	SW#12	8·64 ± 0·28	SW#23	7·25 ± 0·37
	Day	7·15 ± 0·18		7·86 ± 0·24		6·05 ± 0·18
SW#05	Night	6·09 ± 0·68	SW#13	6·05 ± 0·75	SW#24	3·21 ± 0·43
	Day	9·00 ± 0·45		7·18 ± 0·10		7·00 ± 0·32
SW#06	Night	7·65 ± 0·22	SW#14	6·83 ± 0·51		
	Day	8·37 ± 0·43		9·62 ± 0·34		
SW#07	Night	4·67 ± 0·17	SW#15	3·50 ± 0·13		
	Day	7·27 ± 0·26		7·50 ± 0·21		
SW#08	Night	4·50 ± 0·13	SW#16	5·00 ± 0·77		
	Day	8·25 ± 0·13		6·62 ± 0·23		

Sleep length, Total per day sleep including "on j ob sleep".
SW#01 to SW#08 from steel plant; SW#09 to SW# 16 senior nurses; SW# 18 to SW#24, junior nurses from a hospital.

In five out of eight steel plant workers a statistically significant decrease in the per day sleep length was observed. In senior nurses no statistically significant change in per day sleep length was observed, while they were on night shifts. In contrast, in two nurses the sleep length were statistically significantly more during the night shift as compared with the same during other shifts. Only in two senior nurses a significant decrease in sleep hours was noticed.

In one out of five junior nurses, sleep length was more during the night shift and in another it was less during the other shifts. In the remaining three individuals no significant difference in sleep length during the night shift and other shifts were noticed.

3.3b *Sleep quality:* The results of χ^2 test show that the rating of sleep, very good, manageable and bad was dependent upon whether the shift workers were working in the night or other shifts. Out of 82 days during other shifts the steel plant workers rated on 65 days (80%) of having very good sleep, while on night shift, 59% of days (25/43) the sleep was rated very good. The per cent of sleep ratings manageable and bad were 33 % and 7% respectively during the night shifts as compared to other shift ratings of 19 5% and 1%, respectively (figure 4a).

In senior nurses the per cent of sleep rating was very good, 7 5 % during the other shifts and 4 3 % during the night shifts. The per cent of sleep rating manageable and bad during the night shift were 31% and 8 % as compared to 13 % and 3 %, respectively during the other shifts (figure 4a).

In junior nurses the per cent of sleep ratings very good, manageable and bad during the night shift was only 48%, 44% and 8%, respectively. During other shifts the per cent ratings were in the order of 84%, 16% and nil, respectively (figure 4a).

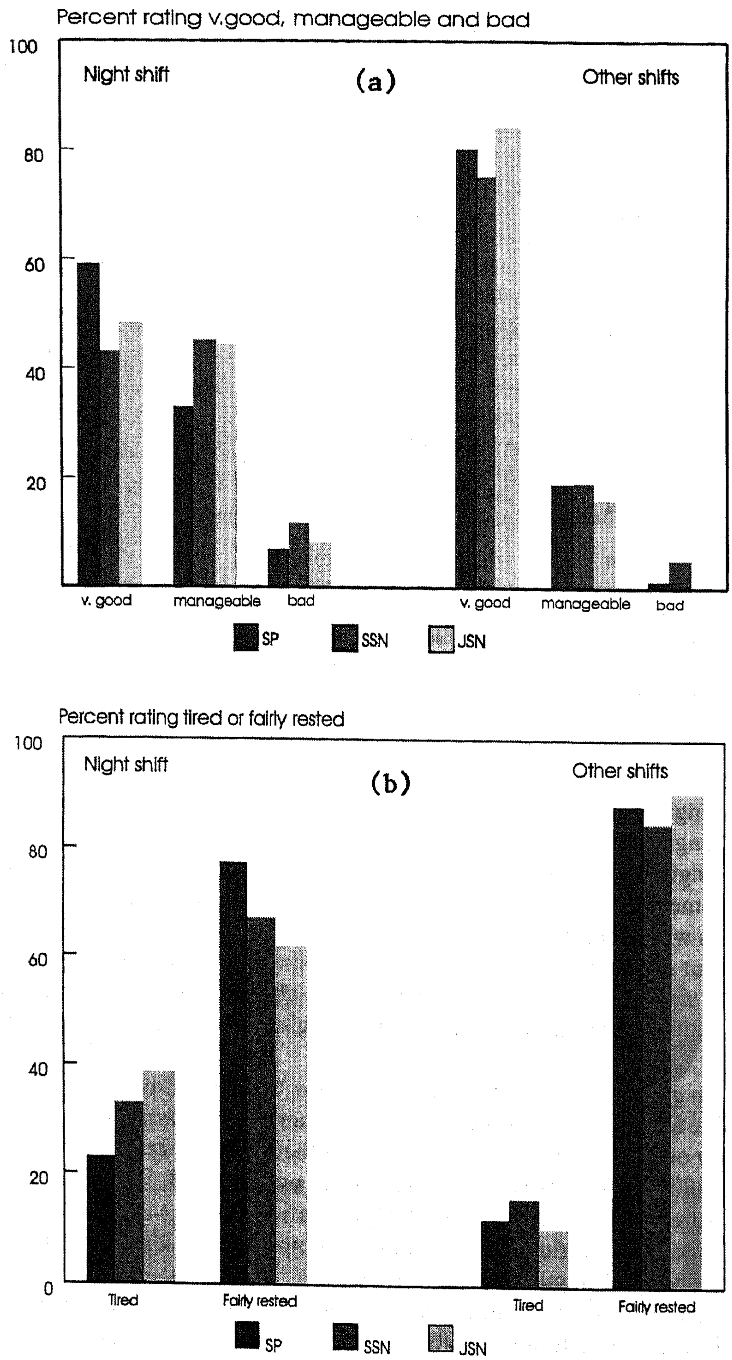

Figure 4. a and b.

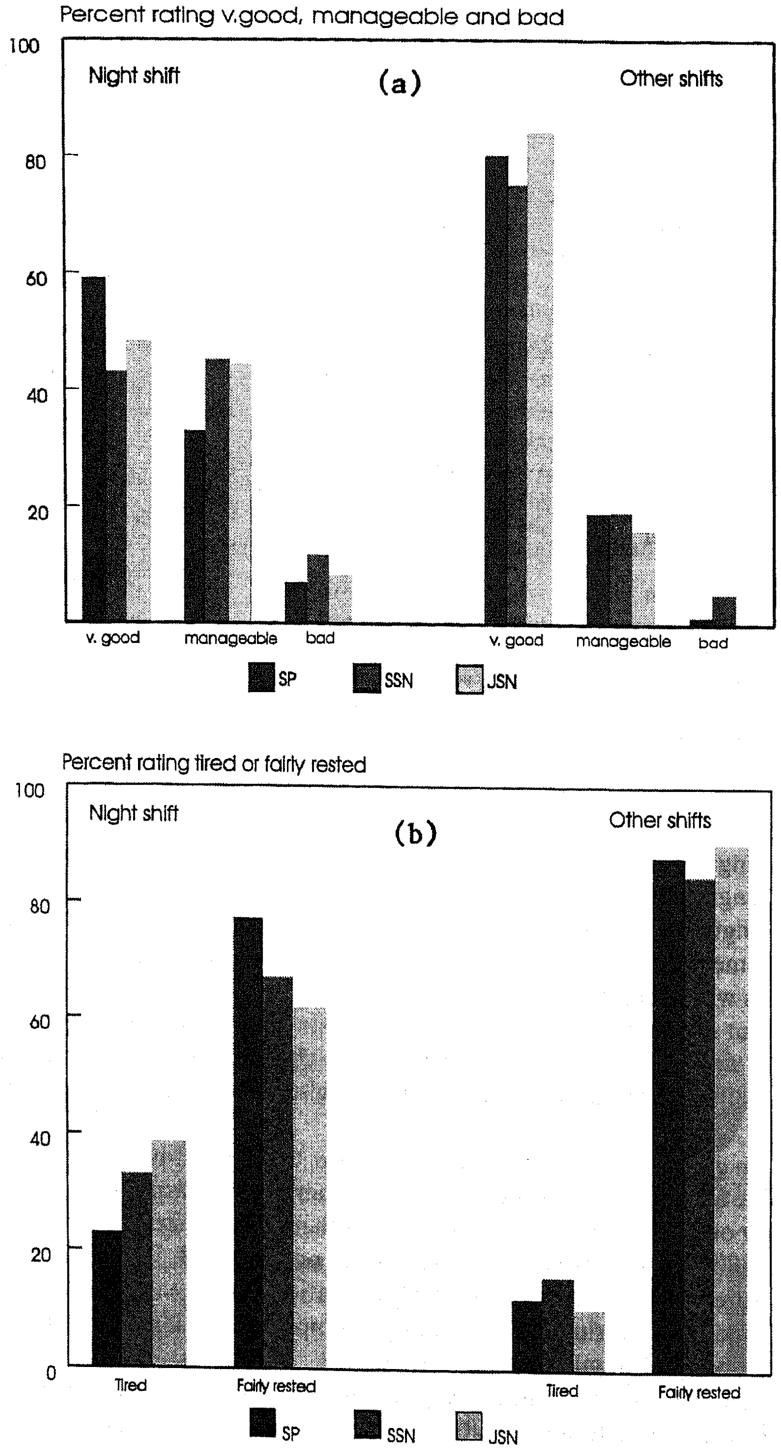

Figure 4. a and b.

Results reconfirm the earlier reports wherein desynchronization of circadian rhythm in oral temperature has been rigorously demonstrated in shift workers (Reinberg *et al* 1980, 1984, 1988; Motohashi *et al* 1987; Aschoff 1983; Folkard 1988; Pati and Saini 1991). Reinberg *et al* (1984) have further distinguished tolerant subjects from those of intolerant shift workers and have demonstrated prevalence of circadian rhythm desynchronization among intolerant shift workers. More often internal desynchronization is not at all demonstrable among tolerant shift workers (Reinberg *et al* 1984, 1988).

Shift work disrupts the normal circadian variation in self-rated fatigue and causes sleep impairment. Shift workers usually suffer from sleep disorders. They most often fail to sleep after the night shift and initiate it before the morning shift (Åkerstedt 1984). On the basis of several studies on the psychological and psychophysiological effects of shift work Åkerstedt (1990) has concluded that the shift workers are prone to sleep disorders as compared to the day workers. Shift work more specially during the night and early morning strongly influences the psychology and psychophysiology of human subjects (Åkerstedt 1984).

We have studied the circadian time structure in shift workers and diurnally healthy human subjects. It was found that the subjective variables, such as fatigue and drowsiness are less prone to desynchronization as compared to other objective parameters, such as oral temperature, heart rate, finger counting speed, and random number addition speed as a consequence of shift work. This was evident from the greater frequency in the detection of circadian rhythms in subjective fatigue (SF) and subjective drowsiness (SDR) among shift workers than in other physiological variables. In steel plant workers the rhythms in SF and SDR exhibited non 24 h non 12 h periods in 17% of instances as opposed to total non-occurrence of such periods in diurnally working healthy human subjects. The incidence of this component was of 22 % in senior nurses and 5% in junior nurses. However, the frequency multiplication was prominent for SF and SDR rhythms among junior nurses (Gupta and Pati 1993, 1994b, 1995). These observed differences could be imputed to the basic differences in shift rotation schedules (Gupta and Pati 1994b).

In an earlier study it has been demonstrated that availability of "on j ob sleep" could not prevent performance decrement in nurses while on night shifts, irrespective of their seniority (Gupta and Pati 1993, 1994b). However, the extent of the level of desynchronization for oral temperature was less in senior nurses as compared to the other two groups. The reason may be lesser frequency of night shifts in case of senior nurses.

When the data on sleep length was analysed it was found that total sleep length was significantly less only in steel plant workers during the week while they were on night shifts. However, despite sufficient per day sleep, including "on job sleep" in the week while on night shifts the nurses exhibited desynchronization of circadian rhythm in oral temperature. This corroborated earlier findings that the total length of per day sleep, may not be important, rather sleep during the appropriate circadian phase is imperative for normal human performance (Gupta and Pati 1993; Czeisler *et al* 1982). Further in permanent night workers it has been shown that they usually have sleep for a longer duration, than rotating shift workers on the night shift (Dahlgren 1981; Kripke *et al* 1971; Bryden and Holdstock 1973).

Several authors support the generalization that at least in man there could be two brain oscillators out of which one regulates oral temperature rhythm and the other sleep/wake cycle (Reinberg *et al* 1988; Folkard *et al* 1983; Aschoff and Wever 1981). All the rhythms are thought to be controlled by one of these two oscillators. Under altered sleep/wake schedules and in conditions of temporal isolation the temperature rhythm and sleep/wake cycle may separate from one another and run with distinctly different periods. Present results suggest that rhythms of SF and SDR are governed neither by the oral temperature oscillator nor by the sleep/wake cycle oscillator. These results support the multioscillatory control of circadian rhythms. Similar suggestion has been made by several other authors for various physiological variables (Reinberg *et al* 1988; Folkard 1990; Monk *et al* 1983).

Present results clearly demonstrate that the type of shift rota is primarily responsible in producing the detrimental effects as gauged by the extent of rhythm desynchronizeation. The shift rota experienced by junior nurses present maximum rhythm desynchronization problems.

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