Recent Research in Science and Technology 2014, 6(1): 268-273
ISSN: 2076-5061
Available Online: http://recent-science.com/

Fitness problem in shift workers while adjusting in ever changing working schedule

Rakesh Kumar Soni

Department of Biotechnology, AVS Presidency International College, Mana, Raipur-492001, Chhattisgarh, India

Abstract
The present study was aimed to assess the diurnal variations in few physiological processes in rotational shift workers suffering irregular life styles due tohaving regular and/or irregular workload during night shift. The diurnal variations in rest-activity was monitored, using wrist actigraphy, in cohorts of 14 shift workers (SWs) employed in the Sponge Iron Manufacturing Industry (SIMI) and 20 shift workers (SWs) of the Chhattisgarh State Electricity Board (CSEB). The former organization adopts regular rotational shift system and the latter an irregular rotational shift pattern. SWs of both organizations worked in a counterclockwise 3-shift system. All SWs were provided an actiwatch around the clock covering all three shifts to monitor their sleep-wake activity pattern. One-minute epoch length was chosen for collection of wrist actigraphy data. Data were analyzed using computations of dichotomy index ($I<O$) and autocorrelation coefficient ($r24$). The irregular rotational SWs from CSEB took rest/ nap/ sleep in the night shift while on duty. Therefore, the activity pattern of these subjects was somewhat similar to that of the day workers. Results of the present study showed that autocorrelation coefficient was significantly ($p < 0.05$) lower in irregular rotational shift workers as compared to regular rotational shift workers only during the morning shift. There are no statistically significant differences between the means of $r24$ obtained for the morning, afternoon, and night shifts, when values were compared separately for each organization. Further, the regular rotational SWs exhibited significantly lower dichotomy index during night shift as compared to morning shift.

Keywords: Circadian rhythm, rest-activity, irregular rotational shift, regular rotational shift, dichotomy index, autocorrelation, circadian period

INTRODUCTION

Homo sapiens have been evolved as a diurnal being: they are attuned to work during the day and to take rest in the night (Gangopadhyay*et al*., 1998). This type of working system is called day work. However, indispensability of the current day shift working, especially night shift does not allow them to stick to their evolutionary dictum. Eventually this unusual work schedule inflicts adverse effects on human health and well being (Pati, 2001). Therefore, it is mandatory to examine the effects of shift working on human health, especially on biological clock that dictates an individual, when to get up and when to sleep.

Shift work forces workers to change their diurnal habits into nocturnal habits. This may eventually leads to complete internal and external rhythm desynchronization in shift workers including sleep/wake cycle disruption and circadian rhythm disruption (Silbergleit*et al*., 2006; Aschoff*et al*., 1975; Moore-Ede *et al*., 1983). As reported above shift workers often experience complete temporal disorganization characterized by both external as well as internal desynchronization of biological rhythms (Reinberg*et al.,* 1984, 1988, 1989; Gupta and Pati, 1994a; Gupta *et al*., 1997; Chandrawanshi and Pati, 2000). Even though the main hazardous effects of shift work are well documented, it is evident that not all individuals are equally affected, while some people suffer and others better tolerate (Akerstedt and Torsvall, 1981; Folkard and Monk, 1981; Härmä, 1993; Reinberg*et al*., 1984). Several individual properties such as, diurnal types, circadian amplitude, sleep flexibility and ages have been investigated as reason of the discrepancy in tolerance (Axelsson*et al*., 2003; Nachreiner, 1998). Further the same has been reported for circadian rhythm in rest/activity and thus the performance of shift workers is affected (Goh*et al*., 2000).

Circadian adaptation to night work requires that circadian rhythm phase shift to reentrain the newly imposed light dark cycle and sleep wakefulness cycle (Sharkey and Eastman, 2002). However, there is still a considerable gap between the implications of chronobiological approach for shift work research and actual practice (Åkerstedt, 1988). Therefore, the aim of the present study was to assess the circadian rhythm in regular and irregular rotational shift workers with heavy or less workload during night shift.

METHOD
Subjects

The rest-activity rhythm was studied in thirty-four subjects consisting of 20 irregular rotational shiftworkers (IRs; age range 24 to 56 years; median age: 35 y) and 14 regular rotational shift workers (RRs). The SWs were randomly selected from two different organizations, namely Chhattisgarh State Electricity Board (CSEB) and Raipur Alloys (RA) characterized by irregular rotational shift, regular rotational shift respectively. All participants gave written consent for their participation in the study. The subjects in the RA and the CSEB routinely experienced heavy and low workload, respectively. Shift workers of both organizations were working in a 3-

*Corresponding Author

Rakesh Kumar Soni
Department of Biotechnology, AVS Presidency International College, Mana, Raipur-492001, Chhattisgarh, India

Email: rakeshsoni08@gmail.com

shift system, characterized by the rotation from night (NS, 22:00-06:00) to afternoon (AS, 14:00-22:00) and to morning shift (MS, 06:00-14:00) in a counterclockwise fashion. Each subject works for six consecutive days on each shift followed by 1-day rest during transition between adjacent shifts. However, in CSEB the rotation was considered irregular, as timings of shifts were not very strictly adhered to on account of mutual adjustments. SW had considerably light workload during the night shift.

Procedure

Each subject wore an Actiwatch (AW64, Mini Mitter Co. Inc., USA), which monitored rest-activity for 21 consecutive days. None of them had a history of major diseases, except occasional digestive troubles among the SWs. No restriction was imposed upon them concerning their sleep schedules and food preferences. The SWs had ample opportunity to have sleep during night shifts.

Statistical analyses

Graphical representation of the rest-activity pattern was obtained in the form of actograms for each subject by using Actiware sleep software (version 3.3). The circadian rhythm characteristics, such as average of the rhythmic function (Mesor, M, rhythm-adjusted 24-h mean), amplitude (A, one-half of the difference between the highest and the lowest value of the rhythmic function), and peak or acrophase (Ø, timing of the highest value of the rhythmic function) were estimated shift wise (Nelson *et al*., 1979) at two different fixed windows, i.e., τ = 24 h and τ = 12. The additional 12-h period was especially selected because bimodality in the activity pattern was detected in the actograms of most of the subjects. Harmonic means were calculated for M, A, and Ø obtained at both windows. The prominent period in each dataset belonging to each subject was computed using the power spectrum method (De Prins*et al*., 1986) that was suitable to analyze time series with or without missing data. Autocorrelation analyses, which do not presume the shape of any cyclic function, were also applied to derive the autocorrelation coefficient at τ = 24 (i.e., *r*24) to obtain another measure of the regularity of the activity pattern over the 24 h. The dichotomy index (*I*<*O)*, *i.e.,* thedifferences in activity distribution between the daily activity and rest spans was also computed(Minors *et al*., 1996). The dichotomy index *I*<*O* is the percentage of the 1 min activity values measured while the subject is in bed that is inferior to the median value when the subject is out of bed. The value of this index can vary between 0% and 100%. In case of a marked circadian rhythm with complete rest at night and high activity during daytime, *I*<*O* tends to reach 100%. Both *r*24 and *I*<*O* were computed shift wise for each subject, including the controls. Other conventional statistical techniques, such asANOVA followed by Duncan's multiple-range test, and *t*-test were also used whenever required.

RESULTS

Rest-activity rhythm

Figure 2.1 A-B represents illustrative examples of double-plotted actograms of rest-activity pattern in an irregular shift worker and a regular rotational shift worker (CRS # 01 and RRS # 03). The irregular rotational shift worker (CRS # 01) displayed more activity during the daytime and rest during the nighttime irrespective of morning, afternoon and night shifts. Whereas, the rest activity cycle of the regular rotational shift worker shifted with the three shifts system.

Circadian rhythm

A statistically significant circadian rhythm in rest-activity with a prominent period of τ = 24 h was validated in both the shift worker groups, irrespective of its computation at fixed windows with or τ = 12 h and shift type. Circadian periodicity (τ = 24 h) appears to be the dominant feature among most of the irregular rotational and regular rotational shift workers irrespective of the shifts. However, few shift workers (n = 8, CRS; n = 2, IRS) showed ultradian rhythm (τ = 12 h) in rest-activity during their night shifts work. Figure 4 (IRS: A - MS, B - AS, C - NS, and CRS: D - MS, E - AS, F - NS) shows illustrative examples of circadian and ultradian prominent periods in rest-activity rhythm of a regular rotational shift worker (CRS # 01 and RRS # 03) while performing morning afternoon and night shifts. Figure 2 illustrates the best-fitting cosine curves based on harmonic averages of 24 h mesor, amplitude and acrophase in a regular rotational shift worker (A: CRS # 01 and B: RRS # 03) during morning, afternoon and night shift.

There were no statistically significant differences between the harmonic averages of 24 h average, amplitude and acrophase obtained for the morning, afternoon, and night shifts, when values were compared separately for irregular rotational organization (Table 1). However, the regular rotational SWs exhibited significantly lower (p<0.05) amplitude and advanced peak during night shift (Table 3). Figure 3 shows illustrative examples of day-to-day changes in peaks of rest-activity rhythm (harmonic mean) in a regular rotational shift worker (CRS # 01 and RRS # 03).

Further, comparison of rhythm characteristics was made between shift workers of CSEB and RA while they worked morning, afternoon and night shifts (Table 5). The results indicated that the amplitude of rest- activity rhythm, was found to be significantly (p<0.01) lower among the RA shift workers, as compared to the CSEB shift workers, while they were in the afternoon and night shift (Table 5). The acrophase was found to be earlier in RA shift workers as compared to the CSEB shift workers during the morning and night shift (Table 5).The peak spread was found to be exceptionally larger in subjects of RA, while they worked night shift.

Dichotomy index (I<O) and Autocorrelation (r24)

Dichotomy index (*I*<*O*) and autocorrelation coefficient (*r*24) were also computed for individual shift workers from irregular rotational and regular rotational shift worker in their respective morning, afternoon and night shifts (Table 2 and 4). In each subject the value of *r*24 was statistically significant irrespective of shifts and organization. A statistically significant difference could not be obtained when means of dichotomy index obtained for morning, afternoon, and night shifts, were compared separately for irregular rotational shift workers (Table 2).However, the regular rotational SWs exhibited significantly lower dichotomy index during night shift as compared to morning shift. Further, there are no statistically significant differences between the means of *r*24 obtained for the morning, afternoon, and night shifts, when values were compared separately for each organization (Table 2 and 4). Moreover, comparison of dichotomy index and autocorrelation was made between shift workers of CSEB and RA while they worked morning, afternoon and night shifts (Table 5). The results indicated that the dichotomy index of irregular rotational shift workers does not differ from that of the regular shift workers while performing morning, afternoon and night shifts (Table 5).It was revealed that the autocorrelation coefficient was significantly (p < 0.05) lower in irregular rotational shift workers as compared to regular rotational shift workers only during the morning shift.

Table 1. Characteristics of rest-activity circadian rhythm in CSEB CRSs as function of shift type.

Shift	24-h average	Amplitude	Peak
Morning Shift	1.56 ± 0.06[a]	0.56 ± 0.04[a]	13.4 ± 0.13[a]
Afternoon Shit	1.59 ± 0.05[a]	0.59 ± 0.03[a]	13.2 ± 0.38[a]
Night Shift	1.60 ± 0.06[a]	0.60 ± 0.03[a]	13.1 ± 0.68[a]
ANOVA Summary (Shift effect):			
24-h average:	F- value = 0.13; df = 2, 49; p = 0.87		
Amplitude:	F- value = 0.41; df = 2, 49; p = 0.66		
Peak:	F- value = 0.10; df = 2, 49; p = 0.90		

Table 2. Characteristics of dichotomy index and autocorrelation obtained for rest-activity rhythm in CSEB CRSs as function of shift type.

Shift	Dichotomy index	Autocorrelation
Morning Shift	96.61 ± 0.61 [a]	0.24 ± 0.02 [a]
Afternoon Shit	97.00 ± 0.40 [a]	0.24 ± 0.02 [a]
Night Shift	96.52 ± 0.41 [a]	0.24 ± 0.02 [a]
ANOVA Summary (Shift effect):		
Dichotomy index:	F- value = 0.30; df = 2, 49; p = 0.74	
Autocorrelation:	F- value = 0.006; df = 2, 51; p = 0.99	

Table 3. Characteristics of rest-activity circadian rhythm in RA CRSs as function of shift type.

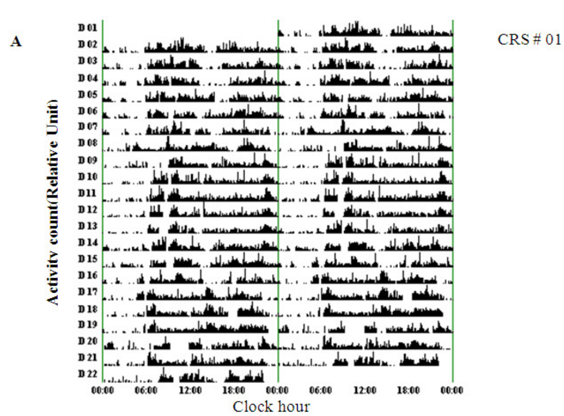
Shift	24-h average	Amplitude	Peak
Morning Shift	1.64 ± 0.04 [a]	0.59 ± 0.03 [a]	11.4 ± 0.25 [ab]
Afternoon Shit	1.62 ± 0.05 [a]	0.49 ± 0.03 [ab]	13.5 ± 0.36 [a]
Night Shift	1.58 ± 0.06 [a]	0.44 ± 0.05 [b]	09.2 ± 1.77 [b]
ANOVA Summary (Shift effect):			
24-h average:	F- value = 0.25; df = 2, 37; p = 0.78		
Amplitude:	F- value = 4.12; df = 2, 37; $\mathbf{p < 0.05^*}$		
Peak:	F- value = 4.44; df = 2, 37; $\mathbf{p < 0.05^*}$		

Table 4. Characteristics of dichotomy index and autocorrelation obtained for rest-activity rhythm in RA CRSs as function of shift type.

Shift	Dichotomy index	Autocorrelation
Morning Shift	97.35 ± 0.37 [a]	0.29 ± 0.02 [a]
Afternoon Shit	96.30 ± 0.55 [ab]	0.28 ± 0.02 [a]
Night Shift	95.61 ± 0.56 [b]	0.27 ± 0.02 [a]
ANOVA Summary (Shift effect):		
Dichotomy index:	F- value = 2.95; df = 2, 37; p = 0.06	
Autocorrelation:	F- value = 0.12; df = 2, 37; p = 0.88	

Table 5. Comparison of rest activity rhythm parameters between CSEBand RA as a function of shift

	CSEB	RA	t- test
Variables	Mean ± SE	Mean ± SE	df ; t value; P value
Morning shift			
M (Mesor)	1.561 ± 0.06	1.64 ± 0.04	26; 1.101; 0.141
A (Amplitude)	0.561 ± 0.04	0.59 ± 0.03	26; 0.590; 0.280
Ø in h (Acrophase)	13.403 ± 0.13	11.45 ± 0.26	18; 6.812; 0.000
DI (Dichotomy index)	96.609 ± 0.61	97.35 ± 0.38	24; 1.044; 0.153
r24 (Autocorrelation)	0.242 ± 0.02	0.29 ± 0.02	27; 1.731; 0.047
Afternoon shift			
M (Mesor)	1.588 ± 0.05	1.62 ± 0.05	29; 0.503; 0.309
A (Amplitude)	0.594 ± 0.03	0.49 ± 0.03	31; 2.262; 0.015
Ø in h (Acrophase)	13.188 ± 0.38	13.55 ± 0.36	31; 0.687; 0.249
DI (Dichotomy index)	97.017± 0.41	96.30 ± 0.55	26; 1.052; 0.151
r24 (Autocorrelation)	0.244 ± 0.02	0.28 ± 0.02	30; 1.343; 0.095
Night shift			
M (Mesor)	1.600 ± 0.06	1.584 ± 0.06	27; 0.181; 0.429
A (Amplitude)	0.600 ± 0.03	0.436 ± 0.05	18; 2.861; 0.005
Ø in h (Acrophase)	13.104 ± 0.68	9.258 ± 1.76	16; 2.034; 0.029
DI (Dichotomy index)	96.522 ± 0.41	95.610 ± 0.56	23; 1.311; 0.101
r24 (Autocorrelation)	0.244 ± 0.02	0.273 ± 0.02	29; 1.005; 0.162



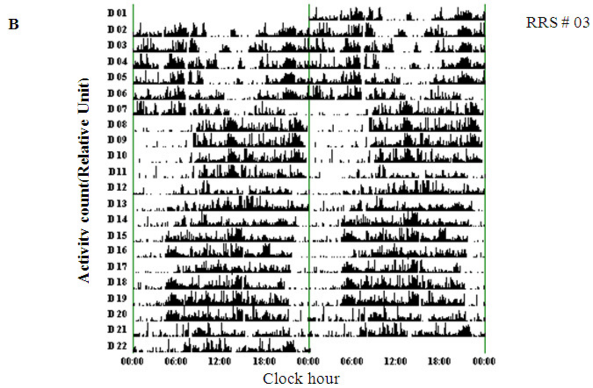


Fig 1.Illustrative examples of double plotted rest-activity profile of a irregular rotational SWs (A: CRS # 01; B: RRS # 12). Rest-activity was monitored for 21 days in free living condition. Although the SW performed rotational shiftwork, there is no difference in the activity pattern as a function of shift (A); The rest and activity spans shifted with respect to night shift (NS), afternoon shift (AS) and morning shift (MS).

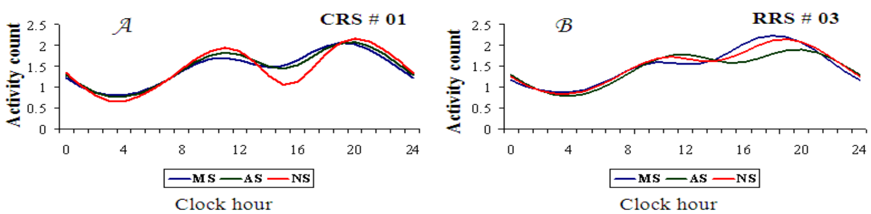


Fig 2. Representative examples of cosine-fitted curve in two irregular rotational SWs and a regular rotational shift worker in morning afternoon and night shift (A: CRS # 01 and B: RRS # 03), based on harmonic means of Mesors, amplitudes and acrophases obtained independently at fixed windows with periods equal to 24 h and 12 h.

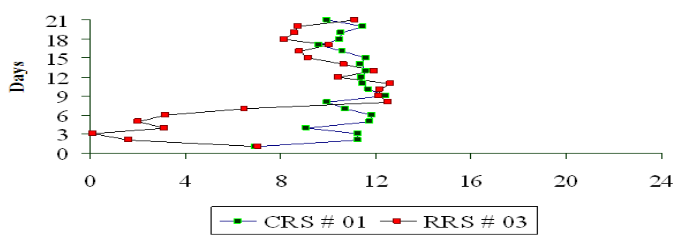


Fig 3.Illustrative examples of day-to-day occurrence of peaks (Harmonic means) in rest-activity rhythm of an irregular rotational SW (CRS # 01) and a regular rotational SW (RRS # 03). The peak spread was more in regular rotational shift worker.

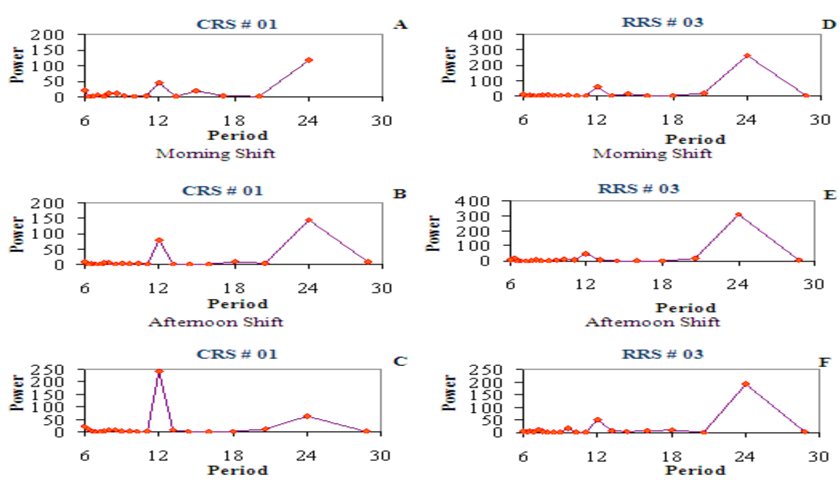


Fig 4 Illustrative examples of prominent periods in rest-activity rhythm of an irregular rotational SW (CRS # 01) and a regular rotational SW (RRS # 03) during morning (A, D: MS), afternoon (B, E: AS) and night shift (C, F: NS).

DISCUSSION

In the present study, the shift workers worked in the Chhattisgarh State Electricity Board (CSEB) substation and Raipur Alloys (Sponge Iron Manufacturing Industry) characterized by substantially low and heavy work load respectively, during the night shifts. They also had irregular and regular rotational shift work schedules respectively.Using a wrist actigraphy technique (with a sampling frequency of 1 minute), the study of the rhythm of activity was recorded in subjects on morning, afternoon and night work. The shift work was characterized clearly by the difference with work load in the rest activity pattern, derived from actigraphy counts. The activity count during the night shift for the irregular rotational shift work group was decreased owing to their taking long naps. It has been pointed out that this strategy probably favored the maintenance of a diurnal orientation (Daurat and Foret, 2004). However, the regular rotational shiftwork group performed intensive physical work and, did not obtain dozing during the night shift. This indicates that regular rotational shift workers were more prone to health risk due to their altered rest-activity rhythm as compared with irregular rotational shiftworkers. Shah (1990) pointed out that non-rotational workers enjoyed more frequent and longer naps and had fewer disturbances in their sleep patterns than rotational workers. There are, however, no clear indications that irregular work hours cause alteration in rest activity rhythm. Though, it has been shown that irregular work hours exert strong, negative effects on sleep, heath, social life and satisfaction of workers (Åkerstedt, 2003; Choobineh*et al*., 2006). In the present study, irregular rotational shift workers adopted napping strategy to restore normal rest activity pattern. This findings corroborate the result of Portela*et al*. (2004), where they did not find significant differences between night and day workers with reference to sleep complaints due to the nature of the shift-work schedule (no successive night shifts) and perhaps nap taking during the night shift. The cross-sectional questionnaire study by Takahashi *et al*. (2005) reported that, male operators at nuclear power plants who reported good adaptation took more frequent, longer nap during night shifts. Further, synchronized rest-activity rhythm characterized by unaltered rhythm parameters observed in the most of the shift workers of irregular rotational shiftworkers could be attributed to the magnitude of workload and nature of their job. Rhythm synchronization was also observed in most of the regular rotational shiftworkers which suggests that they have tolerance to rotational shift work. In the present study it was revealed that the autocorrelation coefficient was significantly lower in irregular rotational shift workers as compared to regular rotational shift workers only during the morning shift. This suggests that the morning shift could be detrimental for the irregular rotational shiftworkers. Moreover, because of the altered work schedules, during night shift, the regular rotational shift workers exhibited significantly lower amplitude and advanced peak as compared to morning and afternoon shift. In contrast, earlier authors found that night workers exhibited, during their work periods, an approximately five-hour delay in the acrophase of their rest/activity rhythm as compared with their rest periods (Delafosse*et al*., 2000). However, their findings were may not be based on harmonic means of acrophase. It is well known that the 24-h pattern of the rest-activity rhythm in humans is shaped more like a square than a sinusoidal waveform; hence the Cosinor method at single window = 24 h is less meaningful in the present context. Therefore, we have calculated harmonic means for M, A, and Ø obtained at two different fixed windows, namely = 24 h and =12 h. We selected 12-h period especially since bimodality in activity pattern was discerned in the periodograms/ actograms of most of the subjects. Further, it was observed that the amplitude of rest- activity rhythm, was found to be declined among the regular rotational shift workers, as compared to the irregular rotational shift workers, while they were in the afternoon and night shift. The decrement in amplitude of circadian rhythm among shiftworkers corroborates the results of previous studies (Soni et al., 2008;Reinberg et al. 1984; Touitou et al. 1990). Acrophase timings alteration occurs due to masking effects of factors, such as greater work load and extended working time, or to the desynchronization of the circadian regulatory system (Stoynev&Minkova 1997). Also, the acrophase was found to be earlier in RA shift workers as compared to the CSEB shift workers during the morning and night shift. However, there has been little previous research on the differences due to workload in connection with rest-activity rhythm during a night shift. We suggest, therefore, that an early start for the morning shift and night work should be avoided as much as possible (Knauth, 1996). CarvalhoBos*et al*. (2003) studied the activity indices that measure the overall activity pattern, activity when out of bed or in bed, or the activity in the hours adjacent to going to bed or getting up of night workers, working 2 to 4 successive night shifts during rest days and night shifts. The dichotomy indices indicated that night work was associated with lower activity when the subjects were out of bed and higher activity when in bed (CarvalhoBos*et al*., 2003). In the present study however, the regular rotational SWs exhibited significantly lower dichotomy index during night shift as compared to morning shift. This phenomenon might be ascribed to misalignment between circadian processes and sleep wakefulness as suggested earlier by Van Dongen (2006). Results of this study conclusively demonstrate that *rotational shift work* whether it is irregular or regularalters circadian rhythm characteristics of shiftworkers significantly because these shifts does not suit the majority of shift workers in terms of tolerability to night work and early morning work. In summary, nature of work modulates the peak and the amplitude of biological clock of shift workers. These results are of immense value for planning optimization of human shift work that may eventually lead to less health problems for the workers and the maximum productivity of the organization.

ACKNOWLEDGEMENTS

This part of work is from thesis of author, thus the Ph.D. guide of the author and relevant supervisor of the work are highly acknowledge.

REFERENCES

[1]Åkerstedt, T. 1988. Sleepiness as a consequence of shift work. Sleep, 11: 17-34.
[2]Åkerstedt, T. 2003. Shift work and disturbed sleep/wakefulness. Occup. Med., 53: 89-94.
[3]Akerstedt, T. and Torsvall, L. 1981. Shift work. Shift-dependent well-being and individual differences. Ergonomics, 24: 265-273.
[4]Aschoff, J., Hoffmann, K., Pohl, H. and Wever, R. 1975. Re-entrainment of circadian rhythm after phase-shifts of the Zeitgeber. Chronobiologia, b: 23-78.
[5]Axelsson, J., Åkerstedt, T., Kecklund, G., Lindqvist, A. and Attefors, R. 2003. Hormonal changes in satisfied and

dissatisfied shift workers across a shift cycle. J. Appl. Physiol., 95: 2099-2105.

[6]CarvalhoBos, S., Waterhouse, J., Edwards, B., Simons, R. and Reilly, T. 2003 The Use of actimetry to assess changes to the rest–activity cycle. Chronobiol. Int.,20: 1039-1059.

[7]Chandrawanshi, A. and Pati, A. K. 2000. Could externally desynchronized circadian rhythm be resynchronized in shift workers? Biol. Rhythm. Res. 31, 160-176.

[8]Choobineh, A., Rajaeefard, A. and Neghab, M. 2006. Problems related to shift work for health care workers at Shiraz University of Medical Science. East. Mediterr. Health. J., 12: 340-346.

[9]Daurat, A. and Foret, J. 2004. Sleep strategies of 12-hour shift nurses with emphasis on night sleep episodes. Scand. J. Work. Environ. Health, 30: 299-305.

[10] De Prins, J., Cornelissen, G. and Malbecq, W. 1986. Statistical procedures in chronobiology and chronopharmacology. Annu. Rev. Chronopharmacol., 2:27-141.

[11] Delafosse, J.Y., Léger, D., Quera-Salva, M.A., Samson, O. and Adrien, J. 2000. Comparative study of actigraphy and ambulatory polysomnography in the assessment of adaptation to night shift work in nurses. Rev. Neurol. (Paris), 156: 641-645.

[12] Folkard, S. and Monk, T.H. 1981. Individual differences in the circadian response to a weekly rotating shift system. In “Night and shift Work: Biological and Social Aspects” (A. Reinberg, N. Vieux and P. Andlauer, eds.), pp. 367-374. Oxford, UK: Pergamon.

[13] Gangopadhyay, A., Chandrawanshi, A. and Pati, A.K. 1998. Assessment of pulmonary function in young and elderly shift workers of a steel plant. Biol. Rhythm Res.29: 272-285.

[14] Goh, V.H.H., Tong, T.Y.Y. and Lee, L.K.H. 2000. Sleep/wake cycle and circadian disturbances in shift work: strategies for their management-A Review. Ann. Acad. Med. (Singapore), 29: 90-96.

[15] Gupta, S. and Pati, A.K. 1994a. Desynchronization of circadian rhythms in a group of shift working nurses: Effects of pattern of shift rotation. J. Human Ergol. 23: 121-131.

[16] Gupta, S., Pati, A.K. and Lévi, F. 1997. Pattern of shift rota modulates oral temperature circadian rhythm and sleep-wakefulness profiles in shift workers. J. Biosci.22: 477-488.

[17] Härmä, M. 1993. Individual differences in tolerance to shiftworks:areview.Ergonomics, 36: 101-109.

[18] Knauth, P. 1996. Designing better shift systems. Appl. Ergon., 27: 39-44.

[19] Minors, D., Waterhouse, J., Folkard, S. and Atkinson, G. 1996. The difference between activity when in bed and out of bed. III. Nurses on night work. Chronobiol. Int., 13: 273-282.

[20] Moore-Ede, N.C., Czeisler, C.A. and Richardson, G.S. 1983. Circadian timekeeping in health and disease. Part 1. Basic properties of circadian pacemakers. N. Engl. J. Med., 309: 469-476.

[21] Nachreiner, F. 1998. Individual and social determinants of shiftwork tolerance. Scand. J. Work Environ. Health, 24 (Suppl 3): 35-42.

[22] Nelson, W., Tong, Y.L., Lee, J.K. and Halberg, F. 1979. Methods for Cosinor-rhythmometry. Chronobiologia, 6: 305-323.

[23] Pati, A.K. 2001. Chronobiology: The dimension of time in biology and medicine. Proc. Indian Natn. Sci. Acad. (PINSA) B67, 323-372.

[24] Portela, L.F., Rotemnberg, L. and Waissmann, W. 2004. Self-reported health and sleep complaints among nursing personnel working under 12 h night and day shifts. Chronobiol. Int., 21: 859-870.

[25] Reinberg, A., Andlauer, P., De Prins, J., Malbecq, W., Vieux, N. and Bourdeleau, P. 1984. Desynchronization of the oral temperature circadian rhythms and intolerance to shift work. Nature,308: 272-274.

[26] Reinberg, A., Motohashi, Y., Bourdeleau, P., Andlauer, P., Lévi, F. and Bicakova-Rocher, A. 1988. Alteration of period and amplitude of circadian rhythms in shift workers. Eur. J. Appl. Physiol.57: 15-25.

[27] Reinberg, A., Motohashi, Y., Bourdeleau, P., Touitou, Y., Nouguier, JEAN, Nouguier, J., Levi, F. and Nicolaï, A. 1989. Internal desynchronization of circadian rhythms and tolerance of shift work. Chrobiologia16: 21-34.

[28] Shah, M.Z. 1990. Sleep and wakefulness pattern of nurses engaged in rotational shift work. J. Pak. Med. Assoc., 40: 245-246.

[29] Sharkey, K.M. and Eastman, C.I. 2002. Melatonin phase shifts human circadian rhythms in a placebo-controlled simulated night-work study. Am. J. Physiol. Regulatory Integrative Comp. Physiol., 282: R454-R463.

[30] Silbergleit, R., Kronick, S.L., Philpott, S., Lowell, M.J. and Wagner, C. 2006. Quality of emergency care on the night shift. Academic Emergency Medicine, 13: 325-330.

[31] Soni, R.K., Dubey, P., Kar, A., Parganiha, A., Pradhan, R.K. and Pati, A.K. 2008. Permanent night work alters characteristics of circadian rhythm of rest-activity in human subjects. Biol. Rhythm Res.,39(6): 481-492.

[32] Stoynev, A.G. and Minkova, N.K. 1997. Circadian rhythms of arterial pressure, heart rate and oral temperature in truk drivers. Occup. Med. (Lond), 48:75-79.

[33] Takahashi, M., Tanigawa, T., Techibana, N., Mutou, K., Kage, Y., smith, L. and Iso, H. 2005. Modifying effects of perceived adaptation to shift work on health, wellbeing, and alertness on the job among nuclear power operators. Ind. Health, 43: 171-178.

[34] Touitou, Y., Motohashi, Y., Reinberg, A., Touitou, C., Bourdeleau, P., Bogdan, A. and Auzéby, A. 1990. Effect of shift work on the night-time secretory patterns of melatonin, prolactin, cortisol and testosterone. Eur. J. Appl. Physiol. Occup. Physiol., 60: 288-292.

[35] Van Dongen, H.P.A. 2006. Shift work and inter-individual differences in sleep and sleepiness. Chronobiol. Int., 23: 1139-1147.