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Time-related Changes in Sleep-Wake Pattern as Correlates of Controlled Shift Work Rotating Directions†

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= Abstract = **In order to elaborate the sleep-wake pattern changes manifested during controlled shift working of counterclockwise and clockwise rotations, eleven subjects were studied. A baseline sleep survey during uncontrolled shift working using a sleep questionnaire revealed that day and night shifts were found to have less total sleep time compared with evening and off duties, with delayed retire time in the evening shifts and advanced rise time in the day shifts. In analyses of data from controlled shift work schedules of opposite directions, difference in rise time appeared to be a crucial factor determining the total sleep time. This finding is compatible with the theory that rise time is one of the most powerful factors in resetting the biological clock. Retire time seemed to be determined more by the subjects' sleep habits and/or the socio-environmental stimuli. Off-duty allocation was found to be an important variable in sleep-wake pattern modulation in shift working.**

Key Words: *Shift work, Counterclockwise rotation, Clockwise rotation, Rise time, Retire time, Total sleep time*

INTRODUCTION

Shift work has developed itself as an inevitable product of industrialized societies. With the invention of electrical light, shift working in the nighttime increased to a tremendous degree in order to meet with increasing productivity as well as satisfying consumer needs in various fields including medical care facilities(Coleman 1986). Shift working is presently a very popular work format and approximately 20% of adult workers in the U. S. are reported to be exposed to it(Lee 1992). In shift working, a new time dimension is introduced, the conventional sleep-wake rhythm is profoundly disturbed and consequently physical, mental, and social disturbances develop. Shift working by its nature enforces shift workers to perform their daily routines and jobs in a physiologically compromised time schedule, such as retiring to bed in the daytime, waking up in the afternoon, and working at night. Health and quality of life problems reported to be related to shift working are indigestion, peptic ulcer, fatigue, emotional instability, depression, interpersonal difficulties, and lowered performance(Aschoff 1978; Folkard *et al.* 1985; Reinberg 1986; Kundi 1989; Monk 1989; Doghramji 1990; Fossey 1990; Skipper *et al.* 1990; Glazner 1991; Kim *et al.* 1991; Hwang *et al.* 1991).

Efforts have been made to improve health and performance in shift workers and possibly prevent the development of shift work-related

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disturbances or illnesses. Studies so far have dealt mainly with direction of rotation or phase shift interval(Moses *et al.* 1978; Czeisler *et al.* 1982; Orth-Gomer 1983; Kundi 1989; Wilkinson *et al.* 1989).

In our previous study(1993), we found that clockwise rotation was more efficient in terms of adjusting back to the usual sleep-wake rhythm of the subjects during the adjustment period after the completion of shift work schedules. However, we were not able to examine the within-shift work changes in which one tried to adapt oneself to changing sleep-wake requirements during different shifts.

The authors in this study attempted to clarify the time-related changes of sleep-wake rhythm during shift work schedules depending on the rotation direction in addition to baseline sleep quality and quantity depending on the different mode of shift.

SUBJECTS AND METHODS

Eleven psychiatric nurses in shift working module were recruited as the study subjects and informed consent was obtained from each of them. Inclusion criteria were decided from a literature survey in order to control as far as possible various conditions affecting shift work adaptation(Tepas and Monk 1987; Reinberg *et al.* 1989) and were as follows: no previous or present history of sleep disorders, single, female, aged below 30, and less than one hour of one-way commuting time.

Before the onset of controlled shifts, we asked each subject to complete a sleep questionnaire in order to assess the baseline sleep-wake pattern in an uncontrolled shift work setting. The sleep questionnaire was developed as modified from Miles' sleep questionnaire and assessment of wakefulness(1979). The important items were usual sleep period time when not in shift working, sleep period time as correlate of shift mode, sleep disturbances as correlates of shift mode, and shift preference. A five point scale, from 0 ("none") to 4("very severe"), was used for assessing the sleep disturbances.

Morningness-eveningness questionnaire (Horne and Östberg 1976) was administered to each subject in order to assess the subject's circadian type. It included 19 items and each item had a score ranging from 0 to 6. Total sum of scores ranged from 16 to 86. Circadian type assessment criteria depending on the total sum of scores were as follows: definitely morning type(70-86), moderately morning type(59-69), neither type(42-58), moderately evening type(31-41), definitely evening type(16-30).

Two different types of controlled shift work schedules, ie. counterclockwise(CCW) and clockwise(CW) rotations, were adopted and applied to each subject consecutively with an interval of one to four weeks' uncontrolled duty period. CCW shift schedule consisted of 3 day shifts(0700-1500 hours), 1 day off, 3 night shifts (2200- 0730 hours), 1 day off, 3 evening shifts (1430-2230 hours), and 1 day off. CW shift schedule consisted of 3 evening shifts, 1 day off, 3 night shifts, 1 day off, 3 day shifts, and 1 day off. Each subject was asked to fill in a daily sleep log during each type of controlled shift work rotation schedule. The content included retire time, rise time, frequency and duration of napping, and gross activity.

SPSS/PC ver. 3.0 was used for statistical analyses. Analysis of variance(ANOVA) with multiple comparison, paired t-test, Kruskal-Wallis one-way ANOVA, Mann-Whitney test, and Wilcoxon matched-pairs signed-ranks test were employed. Significance levels of 0.05 in parametric tests and 0.1 in nonparametric tests were adopted.

RESULTS

The subjects' ages ranged from 25 to 30 years(mean±SD 26.5±1.97). Shift working experience ranged from 1 to 8 years(mean±SD 3.5±1.75). Circadian type scores determined with Horne and Östberg's morningness-eveningness questionnaire ranged from 33 to 60(mean±SD 42. 5±1.97). Depending on the total scores, out of 11 subjects, 7 neither types, 1 moderately

Table 1. Sleep habits and disturbances in uncontrolled(baseline) shift working

Variables (mean ± SD)	Shift Mode			
	Day	Evening	Night	Off
Retire time	23:15 ± 0.93	24:50 ± 0.97	09:10 ± 0.60	23:40 ± 1.12
Rise time	05:45 ± 0.35	09:28 ± 1.00	15:45 ± 2.00	08:15 ± 1.42
TST	6.35 ± 0.83	8.35 ± 0.99	6.91 ± 1.81	8.59 ± 1.04
DFA	2.23 ± 1.51	1.86 ± 1.52	0.82 ± 1.06	-
DMS	2.09 ± 1.24	1.27 ± 1.21	2.82 ± 1.42	-
DOR	2.68 ± 1.12	0.55 ± 0.72	3.41 ± 1.02	-

TST: total sleep time in hours
DFA: degree of difficulty falling asleep
DMS: degree of difficulty maintaining sleep
DOR: degree of being refreshed in the morning

morning type, and 3 moderately evening types were categorized with no extreme types found. All the subjects except one preferred evening shift after completing night shift, because there was sufficient time permitted for sleeping. Meanwhile, day shift was chosen as the ideal shift for social activity by all the subjects.

Findings Reported from Sleep Questionnaire Regarding Baseline Sleep Quality and Quantity

Baseline(uncontrolled shift work period) sleep quality and quantity obtained from the subjects with the sleep questionnaire is as shown in Table 1. Total sleep time(TST) as correlates of shift modes revealed that there were significant differences among the four groups(ANOVA, $F=7.35$, $p=0.0005$). In day and night shifts, TST was significantly shorter than in evening or off duty(Tukey, $p<0.05$). No difference of TST was noted between day and night shifts as well as between evening shift and off-duty.

Regarding nocturnal sleep(excluding sleep after night shift), the subjects retired to bed at an earlier time in day or off duty than in evening shift(Mann-Whitney, $Z=-3.18$, $p=0.002$; $Z=-2.58$, $p=0.01$, respectively). Between off-duty and day shift, no significant difference in retire time was observed. Comparison of rise time among the three groups revealed that the subjects woke up at an earlier time in day shift than in evening or off duty(Mann-Whitney, $Z=-4.02$, $p=0.0001$; $Z=-3.79$, $p=0.0002$, respectively). No significant difference was noted between evening shift and off-duty.

Analysis of overall sleep quality including sleep initiation, maintenance, and degree of being refreshed upon waking showed significant differences depending on the shift mode. Sleep initiation difficulty was most prominent in day shift, moderate in evening shift, and least prominent in night shift(Kruskal-Wallis one-way ANOVA, $X^2=5.25$, $p=0.07$). Sleep maintenance was easiest in evening shift, moderate in morning shift, and most difficult in night shift (Kruskal-Wallis, $X^2=6.74$, $p=0.03$). Degree of being refreshed upon waking up was highest in evening shift, moderate in day shift, and lowest in night shift(Kruskal-Wallis, $X^2=19.97$, $p=0.0000$).

Findings during Controlled Shift Work Rotation Schedules of Opposite Directions

When observed along the progression of the shift work schedule(Figure 1 and Table 2), significant differences in retire time between CCW and CW shift work schedules were found on day 1, 2, 3, 9, 10, and 11(Wilcoxon matched-pairs signed-ranks test, $p<0.1$). With

Table 2. Comparison of retire and rise times between counterclockwise(CCW) and clockwise(CW) shift work schedules.

Progression of days and shift mode (CCW/CW)	Retire time (mean ± SD)				Rise Time (mean ± SD)			
	CCW	CW	Z	p	CCW	CW	Z	p
Day 1(D/E)	-1.30 ± 1.86	0.95 ± 0.94	-2.80	0.005*	6.05 ± 0.32	8.64 ± 1.24	-2.85	0.004*
Day 2(D/E)	-0.55 ± 1.11	1.33 ± 1.33	-2.93	0.003*	5.75 ± 0.40	8.82 ± 0.70	-2.93	0.003*
Day 3(D/E)	-0.23 ± 1.57	1.14 ± 1.05	-2.17	0.03*	9.24 ± 1.47	9.79 ± 1.67	-1.18	0.24
Day 4(O/O)	0.22 ± 1.52	0.96 ± 1.61	-0.71	0.48	9.41 ± 1.11	9.53 ± 2.02	-0.06	0.95
Day 5(N/N)	8.89 ± 0.61	9.20 ± 0.87	-0.84	0.40	15.54 ± 1.52	14.92 ± 1.95	-0.44	0.66
Day 6(N/N)	9.21 ± 0.68	8.99 ± 0.66	-1.47	0.14	16.77 ± 1.20	14.72 ± 1.75	-2.62	0.01*
Day 7(N/N)	9.23 ± 0.96	9.82 ± 2.33	-0.05	0.96	14.30 ± 2.73	14.29 ± 2.72	-0.42	0.67
Day 8(O/O)	0.15 ± 1.25	0.18 ± 1.83	-0.09	0.93	9.40 ± 1.13	5.77 ± 0.30	-2.93	0.003*
Day 9(E/D)	0.75 ± 0.89	-1.27 ± 2.38	-2.40	0.02*	9.57 ± 0.61	5.85 ± 0.42	-2.80	0.005*
Day 10(E/D)	1.28 ± 0.99	-0.27 ± 1.44	-2.58	0.01*	9.84 ± 1.00	5.78 ± 0.38	-2.93	0.003*
Day 11(E/D)	1.03 ± 0.71	0.36 ± 1.38	-1.83	0.07*	8.86 ± 0.77	8.33 ± 1.29	-1.30	0.19
Day 12(O/O)	0.25 ± 1.57	0.18 ± 1.89	-0.91	0.36	5.80 ± 0.57	5.91 ± 0.47	-0.53	0.59

D: day shift ; E: evening shift; N: night shift; 0: off-duty. Retire time calculated as difference from 12:00 midnight(= 0.00); (-) and (+) denote before and after 12:00 midnight respectively. Differences between CCW and CW analyzed with Wilcoxon matched-pairs singed-ranks test(* p〈0.1).

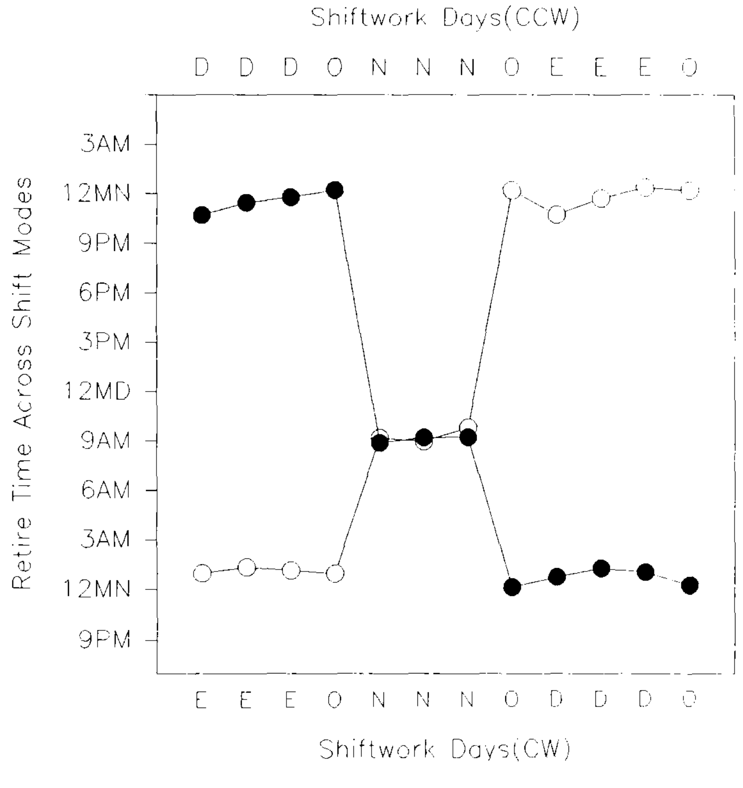

Fig. 1. Retire time change along the progression of shift work days in counterclockwise(CCW) and clockwise(CW) schedules. Closed circles denote retire times in CCW; open circles denote retire times in CW. D: day shift; E: evening shift; N: night shift; 0: off-duty.

the mode of duty discordant(day/evening or evening/day) in those days, the subjects retired to bed at a later time when bound with evening shifts. As shown in Table 4, day, evening, or night shift when compared concordantly between CCW and CW revealed no differences.

Rise time when compared between CCW and CW as shown in Figure 2 and Table 2 revealed significant differences in the 1st, 2nd, 8th, 9th, and 10th day(Wilcoxon matched-pairs signed-ranks test, $p \leq 0.005$). In those days, where the mode of duty was discordant between CCW and CW(day/evening or evening/day), the subjects were found to wake up at an earlier time when bound with day shifts.

On the 6th day(the 2nd night shift in both CCW and CW) the subjects woke up earlier in CW than in CCW(Wilcoxon, $p=0.01$). As shown in Table 4, in evening and night shifts, earlier rise time was observed in CW than in CCW (Wilcoxon, $p=0.03$), while rise time bound with day shift did not differ between CCW and CW.

The mean(±SD) TST in CCW was 7.81(± 0.41) hours and was found to be longer than 6.91 (±0.72) hours in CW(paired t-test, $t=4.58$, $p=$

Table 3. Comparison of total sleep time(TST) between counterclockwise(CCW) and clockwise(CW) shift work schedules

Progression of days and shift mode (CCW/CW)	Permitted rest time (CCW/CW)	TST (mean ± SD)			
		CCW	CW	t	p
Day 1(D/E)	16 /16	7.73 ± 1.48	8.08 ± 1.98	-0.76	0.47
Day 2(D/E)	16 /16	6.40 ± 1.20	7.46 ± 1.94	-1.88	0.09
Day 3(D/E)	27 /19.5	10.54 ± 2.88	8.61 ± 1.72	2.50	0.03*
Day 4(O/O)	28 /28	9.91 ± 1.60	9.19 ± 2.36	1.01	0.33
Day 5(N/N)	14.5/14.5	7.15 ± 1.51	6.32 ± 2.63	1.31	0.40
Day 6(N/N)	14.5/14.5	7.64 ± 0.88	5.91 ± 1.59	4.14	0.002*
Day 7(N/N)	10.5/10.5	4.98 ± 2.47	4.16 ± 1.85	1.19	0.26
Day 8(O/O)	20.5/13	9.01 ± 1.45	5.50 ± 1.85	4.50	0.001*
Day 9(E/D)	16 /16	8.59 ± 1.19	7.03 ± 2.67	1.98	0.08
Day 10(E/D)	16 /16	8.57 ± 1.21	6.60 ± 1.35	3.92	0.003*
Day 11(E/D)	19.5/27	7.67 ± 0.99	8.85 ± 2.44	-1.70	0.12
Day 12(O/O)	13 /13	5.60 ± 1.39	5.42 ± 2.08	0.27	0.80

D: day shift ; E: evening shift; N: night shift; O: off-duty. Permitted rest time defined as the maximum amount of time in hours permitted to have sleep between contiguous shift periods; cut-off point of 6:00pm was adopted for off-duty days. Differences between CCW and CW analyzed with paired t-test (* p⟨0.05).

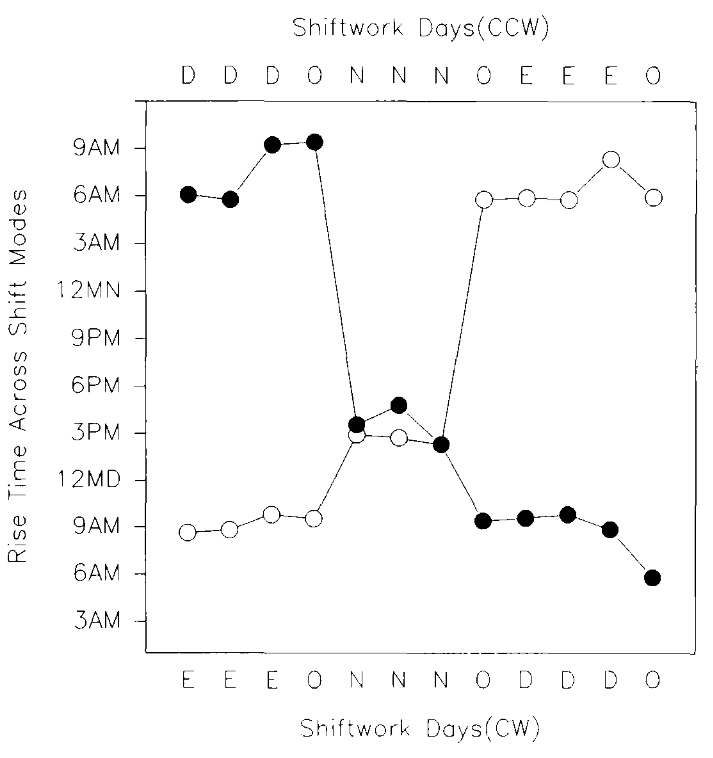

Fig. 2. Rise time change along the progression of shift work days in counterclockwise (CCW) and clockwise(CW) schedules. Closed circles denote rise times in CCW; open circles denote rise times in CW. D: day shift; E: evening shift; N: night shift; 0: off-duty.

0.004). As shown in Table 3 and Figure 3, TST when compared between CCW and CW revealed that TST in CW was significantly shorter in the 3rd, 6th, 8th, and 10th of shift work days(paired t-test, p⟨ 0.05). In evening and night shifts, TST was longer in CCW than in CW(paired t-test, $p \leqslant 0.05$), while TST bound with day shift did not differ between CCW and CW(Table 4).

Analysis of napping behavior in duration and frequency revealed no significant differences between CCW and CW.

DISCUSSION

Sleep-wake rhythm disruption may be the most prominent compromise of normal physiology caused by shift working. Elaboration of changes in the sleep-wake pattern could contribute to further understanding of shift working as well as promoting the development of better-designed shift work schedules(Weitzman and Pollack 1979; Rose 1984; Turek 1986; Fossey 1990; Glazner 1991). In that context, the authors attempted to elaborate the changes

Table 4. Sleep variables as correlates of shift mode in controlled shift working

Variables (mean ± SD)	CCW	CW	t or Z	p
TST				
Day	7.07 ± 0.84	6.82 ± 1.32	0.73	0.48
Evening	8.58 ± 1.01	7.77 ± 1.64	2.19	0.05*
Night	6.59 ± 1.14	5.46 ± 0.91	4.51	0.001*
Retire time				
Day	-0.69 ± 1.10	-0.39 ± 1.40	-0.67	0.50
Evening	1.03 ± 0.86	1.14 ± 0.73	0.00	1.0
Night	9.08 ± 0.54	9.29 ± 0.85	-0.05	0.96
Rise time				
Day	5.90 ± 0.29	5.81 ± 0.36	-0.70	0.48
Evening	9.67 ± 0.53	8.73 ± 0.81	-2.19	0.03*
Night	15.52 ± 1.38	14.57 ± 0.96	-2.19	0.03*

TST compared with paired t-test(* $p \leq 0.05$).

Retire and rise times compared with Wilcoxon matched-pairs signed-ranks test(* $p<0.05$).

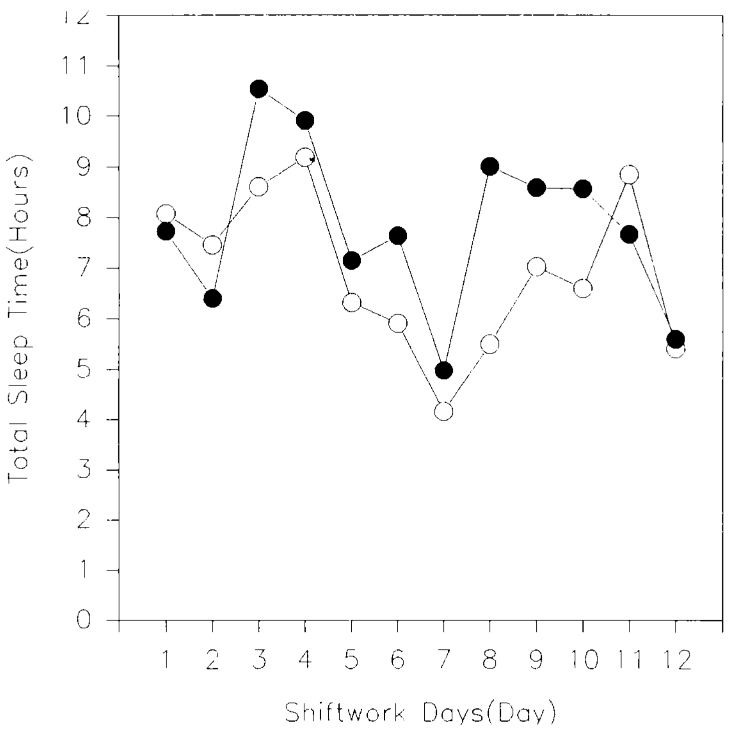

Fig. 3. Total sleep time(TST) change across shift work days in counterclockwise (CCW) and clockwise(CW) schedules. Closed circles denote TSTs in CCW; open circles denote TSTs in CW.

induced by two different shift work schedules consecutively imposed on the same subjects.

During baseline shift working, reportedly more common complaints about overall sleep disturbances occurred in day and night shifts than in evening shift. Surprisingly, in day shift, more complaints related to sleep initiation, maintenance, and not being refreshed upon waking occurred than in evening shift. In night shift, it was easier to fall asleep but more midsleep arousals with decreased refreshment upon waking were reported than in day or evening shifts. In evening shift, it was somewhat difficult to fall asleep but the subjects reported the most refreshing sleep.

The day shifts by their innate nature restrict the amount of time permitted for sleeping, to be on time for 0700 hours. Also, due to the time permitted for activity in the late afternoon and the evening hours, it may be difficult to advance the retire time early enough to obtain sufficient sleep period time. In contrast, the evening shift is very permissive to sleeping in the morning hours with relatively minor delays in retire time. The night shift is theoretically permissive to sufficient sleep period time. However, the permitted sleep period is basically against normal physiology and is very vulnerable to environmental and social stimuli. Therefore, the subjective sleep disturbances tend to be more prominent in day and night shifts. This finding is supported by Akestedt *et al.* (1991).

Sleep logging data during controlled shift schedules showed that the direction of shift rotation had a strong influence on sleep parameters. First of all, TST depended significantly on the rotation direction and the mode of shift including the location of off-duty. Difference in TST between CCW and CW increased in amount as time progressed. Further elaboration on TSTs between CCW and CW showed that TST differences were significant in the period during and after night shifts. Successive partial sleep deprivation is caused by night shifts and involves body temperature rhythm change. And the body temperature rhythm coupled with sleep-wake rhythm appears to react with increasing intensity to shift working, with time-related increase of TST difference between CCW and CW(Mellete *et al.* 1951; Sharp 1961; Conroy and Mills 1970; Eastman 1984; Hildebrant 1987; Harma 1990; De Koninck 1991). Another possibility explaining TST difference could be that rest time permitted between duty shifts varied and consequently the subjects slept more in CCW. Therefore, allocation of off-duty could be a significant variable in promoting adjustment to shift working during the progression of shift work schedules. The possibility is supported by the finding that in CCW compared with CW the off-duty days were allocated in such a way that more generous rest time was permitted.

Analysis of sleep-wake patterns bound with opposite direction of rotation revealed that retire time delay or advance was not significantly dependent on CCW or CW. These findings seem to be contradictory to the general prediction that there should be phase advance in CCW and delay in CW. This may be due to the allocation of off-duty every three days in the shift work schedules, consequently resetting the biological clock and coming back to the usual sleep pattern(Kim *et al.* 1991). Rise time differed depending on the direction of rotation. In evening and night shifts, the subjects in CW rotation woke up earlier than in CCW. Rise time advance in CW without retire time change consequently resulted in decreased TST.

Retire time appears to be influenced more by the subjects' usual sleep habits and/or the socio-environmental stimuli rather than inherent change in sleep physiology induced by different direction of rotation. Meanwhile, rise time seems to be influenced more by innate change of sleep physiology(Daan *et al.* 1984).

According to our data, two factors seem to be important. The mode of shift and the direction of rotation does influence the nature of sleep-wake pattern changes during shift working. Apparently CW rotation seems to be restrictive in terms of TST, however, it provides reciprocally more time for activity. The more activity permitted may consequently improve the quality of sleep in CW(Hauri 1982). The hypothesis is supported by our previous study(1993).

In summary, we observed findings supporting the value of rise time in modulating total sleep time in shift working schedules with different directions of rotation. Also, the innate nature of shift mode and the allocation of off-duty were found to be influential factors in the sleep-wake patterns of shift workers.

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