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Age, sleep and irregular workhours

A field study with electroencephalographic recordings, catecholamine excretion and self-ratings

by Lars Torsvall, MA,¹ Torbjörn Åkerstedt, PhD,¹ Mats Gillberg, MA²

TORSVALL L, ÅKERSTEDT T, GILLBERG M. Age, sleep and irregular workhours: A field study with electroencephalographic recordings, catecholamine excretion and self-ratings. *Scand j work environ health* 7 (1981) 196-203. Day sleep (after night work) and night sleep (after day work) were studied in two groups of locomotive engineers aged 25-35 and 50-60 a, respectively. All recordings were made in the homes of the subjects. For both groups day sleep was reduced by approximately 3.3 h, mainly affecting rapid eye movement sleep and stage 2 sleep. Diuresis and the excretion of noradrenaline were increased during day sleep. The ratings of sleepiness were higher after night work than after day work. Several indices of disturbed daytime sleep correlated significantly with catecholamine excretion. The age groups differed mainly in that the older subjects had relatively more stage shifts, awakenings, stage 1 sleep, a higher diuresis, and a higher noradrenaline excretion during day sleep. It was concluded that night work is detrimental to sleep and that negative effects are exacerbated by increasing age.

Key terms: adrenaline excretion, circadian rhythm, noradrenaline excretion, shift work.

Several survey studies have shown that shift work, particularly the night shift, markedly interferes with sleep and wakefulness. Thus, eg, day sleep after the nightshift is short and subjectively unsatisfactory with respect to recuperation (2, 6, 18). Electroencephalographically (EEG) recorded sleep of shift workers has largely corroborated the subjective reports of day sleep difficulties (11, 15, 16). Essentially, day sleep has been found to be shorter and somewhat redistributed with respect to rapid eye movement (REM) sleep. These studies have concerned individuals on conventional, regularly alternating work schedules. Large occupational groups follow, however, very irregular work schedules. The only EEG study of

this type of group is that of Foret & Lantin (13) of locomotive engineers' sleep. The results of this study indicate very short and redistributed day sleep. Since the design was naturalistic, however, and night sleep in the home was apparently compared with day sleep in dormitories, it is not clear whether a poor sleep environment or daytime per se caused the effects. One purpose of the present investigation was to study the day and night sleep, at home, of locomotive engineers with irregular workhours.

Individual differences may modify the reactions to shift work (20). Survey studies suggest that one such factor of possible importance is age, shift work being increasingly difficult to tolerate with increasing age (7, 12). The ability to obtain satisfactory sleep after the nightshift seems particularly reduced. This effect has not been verified with EEG recorded sleep, however. Thus, another objective of the present investigation was to study age differences in the ability to sleep after night work.

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In contrast to other EEG sleep studies of shift workers, urinary catecholamine excretion, diuresis, and self-ratings were also included among the variables. Especially the first listed has been shown to reflect sleep/wake disturbances of shift workers (1).

Material and methods

Sixteen male locomotive engineers participated in the study. They had very irregular workhours, covering the whole nycthemeron. Half of the subjects were relatively old (50–59 a, mean = 55 a) with long work experience (32 a), while the other half was relatively young (25–37 a, mean = 29 a) with short experience (3 a). The two groups did not differ with respect to any other demographic variables (eg, marital status and housing conditions).

The study began with an habituation night to make the participants familiar with the equipment for sleep registration. This experience was followed by the experimental conditions, one night sleep starting between 2200–2400 (mean 2303) after day work and one day sleep starting between 0600 and 0800 (mean 0736) after night work. The order between the two

conditions was counterbalanced, ie, half of the subjects in each age group had the night sleep first while the other half slept first during the day. The subjects were instructed to sleep as long as they could and not to use any external means of awakening. The rest of the family agreed to help protect the participant from disturbances.

All the recordings were made in the homes of the participants, in their normal sleep environment, which was of high quality and well-separated from the rest of the living quarters. About 45 min before the subject was to go to bed, a member of our team arrived to prepare the subject for the recording. After the subject had phoned to report his awakening, the team member returned to remove the electrodes and collect the recordings.

A four-channel Medilog tape recorder from Oxford Instruments was used to record the EEG (O_2 – P_4) and the electrooculogram (EOG) (bipolar). The scoring of the sleep stages followed the recommendations of Rechtschaffen & Kales (17).

Urine produced during the sleep was collected for hormone analyses (8).

Subjective ratings of sleepiness were made 10 min before and after each period of sleep. A scale from 1 (very, very sleepy)

Fig 1. Sleep length (total sleep time) (mean ± 1 SE) of night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

Fig 2. Sleep latency (mean ± 1 SE) for night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

Fig 3. Absolute amounts (minutes) of different sleep stages (mean $\pm$ 1 SE) during night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately. (W = stage wake, I = stage 1 sleep, II = stage 2 sleep, III = stage 3 sleep, IV = stage 4 sleep, REM = rapid eye movement sleep)

Fig 4. Number of awakenings per hour (mean $\pm$ 1 SE) during night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

Fig 5. Number of stage shifts per hour (mean $\pm$ 1 SE) during night (N) and day (D) sleep for the whole group for the old (o) and young (y) individuals separately.

Fig 6. Adrenaline excretion (mean ± 1 SE) during night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

Fig 7. Noradrenaline excretion (mean ± 1 SE) during night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

to 7 (very, very alert) was used. The subjects also filled out a general questionnaire about the work conditions of locomotive engineers.

The two-tailed t-test was used to test for differences between groups and conditions, respectively (23).

Results

The main results are shown in fig 1–9, and the t-values of the significance tests are presented in table 1. Day sleep was approximately 3.3 h shorter than night sleep. It had a significantly shorter sleep latency and contained significantly smaller amounts of stage 1, stage 2 and stage REM (no percentage differences, however). There was a tendency that REM sleep came earlier during day sleep, but the REM latencies were not significantly different. Furthermore, day sleep was associated with significantly higher diuresis and noradrenaline excretion. No differences between day and night sleep were found for the number of stage shifts, number of awakenings, or adrenaline excre-

Fig 8. Diuresis (mean ± 1 SE) during night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

tion. The subjective ratings showed significantly more sleepiness before day sleep than before night sleep, but no differences were found for the ratings made after the awakening.

Fig 9. Self-rated sleepiness (range 1—7) (mean $\pm$ 1 SE) before and after night (N) and day (D) sleep for the whole group and for the old (o) and young (y) individuals separately.

Table 1. t-Values, with significance levels, of differences between night and day sleep and between old and young subjects.

	All subjects (Night vs day sleep) df = 14	Night sleep (Old vs young subjects) df = 14	Day sleep (Old vs young subjects) df = 13	Old subjects (Night vs day sleep) df = 6	Young sub- jects (Night vs day sleep) df = 7
Sleep length (total sleep time)	6.738***	1.466	0.601	4.331**	4.857**
Sleep latency	2.467*	0.356	0.369	1.255	2.112
Rapid eye movement sleep latency	2.017	0.517	0.825	0.857	2.257
Number of stage shifts	1.521	0.489	2.995*	3.640*	0.323
Number of awakenings	0.899	0.600	2.231*	1.638	0.934
Minutes in stage wake	0.297	0.589	2.764*	0.623	1.249
Minutes in stage 1 sleep	2.247*	0.960	2.414*	1.032	2.118
Minutes in stage 2 sleep	7.672***	0.421	0.265	6.094**	4.875**
Minutes in stage 3 sleep	1.080	0.219	1.138	0.130	1.704
Minutes in stage 4 sleep	1.130	3.189**	3.444**	1.961	0.383
Minutes in rapid eye movement sleep	4.474***	1.437	0.513	2.952*	3.441*
Adrenaline excretion	1.493	2.377*	2.646*	1.214	1.240
Noradrenaline excretion	2.211*	1.536	2.320*	1.888	1.509
Diuresis	3.938**	1.428	1.725	3.765**	1.547
Sleepiness at bedtime	4.054**	0.917	0.978	2.714*	2.826*
Sleepiness at rising	0.414	1.852	0.150	1.333	0.552

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2. Pearson product-moment correlation coefficients, with significance levels, between the variables in the study. The upper part of the matrix shows the scores for the day sleep, and the lower part the night sleep.

	1	2	3	4	5	6	7	8	9
1 Sleep length (total sleep time)	X	0.10	-0.59*	-0.29	-0.17	-0.13	0.76***	0.64**	0.25
2 Sleep latency	-0.23	X	0.20	-0.01	0.00	0.06	0.06	0.35	-0.27
3 Number of stage shifts	0.05	-0.44	X	0.45	0.42	0.38	-0.44	-0.19	-0.56*
4 Number of awakenings	-0.07	0.04	0.44	X	0.95***	0.88***	-0.19	-0.28	-0.41
5 Minutes in stage wake	0.16	0.01	0.44	0.91***	X	0.94***	-0.07	-0.17	-0.44
6 Minutes in stage 1 sleep	0.09	-0.39	0.64**	0.25	0.42	X	-0.19	-0.18	-0.42
7 Minutes in stage 2 sleep	0.64**	-0.26	0.14	0.38	0.58*	0.21	X	0.49	-0.10
8 Minutes in stage 3 sleep	0.28	-0.19	0.27	-0.16	-0.22	-0.21	-0.02	X	-0.20
9 Minutes in stage 4 sleep	0.40	0.07	-0.04	-0.30	-0.24	-0.39	-0.25	0.23	X
10 Minutes in rapid eye movement sleep	0.60*	0.22	-0.60*	-0.42	-0.37	-0.47	0.12	0.05	0.42
11 Adrenaline excretion	-0.13	0.08	0.19	0.22	0.38	0.16	-0.02	0.03	-0.01
12 Noradrenaline excretion	-0.27	0.08	0.10	0.14	0.08	-0.19	-0.34	0.17	0.24
13 Diuresis	0.07	-0.01	0.34	0.49*	0.56*	0.47	0.13	-0.30	-0.12
14 Sleepiness at bedtime	-0.18	-0.07	-0.21	0.16	0.10	0.04	0.13	-0.46	-0.38
15 Sleepiness at rising	-0.10	-0.36	0.37	0.28	0.26	0.29	0.42	-0.04	-0.63**

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The night sleep values differed significantly between the age groups only with respect to stage 4 sleep and adrenaline excretion, which were significantly higher and lower, respectively, in the younger group. A similar difference was obtained also for day sleep, but in addition the older subjects also showed significantly more minutes in wakefulness and stage 1, more stage shifts, more awakenings, and a higher noradrenaline excretion. The age groups did not differ with respect to diuresis or self-ratings.

The correlation matrix (table 2) shows a positive correlation between sleep length and minutes in stage 2 and REM for both night and day sleep. Short day sleep was associated with many stage shifts and a high adrenaline excretion. These two variables, together with noradrenaline excretion, also had a high correlation with one another, and they were negatively correlated with minutes in stage 4 sleep. Furthermore, sleep latency correlated positively with adrenaline and noradrenaline excretion during day sleep. During night sleep stage shifts were connected with the amount of stage 1 sleep and REM sleep (the latter negatively). The only significant correlations involving subjective ratings showed that ratings of sleepiness before day sleep and after night sleep were associated with more stage 4 sleep.

Discussion

The day sleep of the locomotive engineers with irregular workhours was clearly shortened and in other ways disturbed. The results agree with those for locomotive engineers studied by Foret & Lantin (13), as well as with those of studies of regularly alternating shift workers (11, 15, 16). Thus day sleep length is altered in a similar manner irrespective of whether the setting is one of regularly or irregularly alternating workhours. The subjects slept in their homes in a comfortable and silent sleep environment and nobody indicated disturbance by noise. Thus the reason for the short day sleep is probably the circadian rhythm of the propensity for sleep which reaches a trough during the day (5).

The sleep latency was shorter before day sleep than before night sleep and was therefore in agreement with the diurnal rhythm of sleep latency shown by Webb & Agnew (22).

In our study the adrenaline excretion did not differ between day and night sleep, a finding which agrees with previous results from experienced shift workers (1, 3). Noradrenaline excretion differed however between night and day sleep. For the disturbed day sleep catecholamine excretion was associated with shorter sleep length, longer sleep latency, more frequent stage shifts, and less stage 4 sleep. It seems reasonable that disturbed sleep could be characterized by higher adrenomedullary activity, and the possibility that this activity might serve as an indicator of sleep quality should be pursued in further studies.

Diuresis was doubled during day sleep, apparently due to the circadian rhythm of diuresis (10), even if uncontrolled fluid intake might have contributed. Irrespective of the cause it is possible that diuresis may be contributing to the differences in sleep length between night and day sleep. At a rate of 1.8 ml/min the desire to urinate (300- to 700-ml bladder volume) would be reached in less than 3 h. Nothing is known about the effects of this phenomenon on sleep, however, and there was no significant correlation between diuresis and sleep length, but only between diuresis and number of awakenings during night sleep.

Table 2. (continued).

10	11	12	13	14	15
0.83***	-0.60*	-0.38	-0.13	-0.18	0.10
0.13	0.55*	0.57*	0.01	0.02	-0.21
-0.41	0.64**	0.72**	0.02	0.16	-0.25
-0.35	0.44	0.24	0.09	0.37	-0.29
-0.28	0.16	0.31	0.17	0.25	-0.33
-0.08	0.40	0.21	0.23	0.25	-0.19
0.36	-0.37	-0.15	-0.23	0.19	-0.08
0.52*	-0.11	-0.06	0.06	-0.23	0.11
0.19	-0.66**	-0.50*	-0.14	-0.62*	0.09
X	-0.49	-0.35	-0.02	-0.12	0.28
-0.36	X	0.82***	0.04	0.14	-0.11
-0.21	0.77***	X	-0.07	-0.03	-0.29
-0.14	0.54*	0.34	X	0.03	0.23
-0.09	0.03	0.02	0.30	X	0.00
-0.36	0.05	-0.23	0.24	0.46	X

For day sleep the extended prior wakefulness and short sleep length would be expected to result in increased postsleep sleepiness. Unexpectedly, this was not the case. Since the rating scale was sensitive to the difference in sleepiness between the two bedtimes, the reason is probably not insensitivity of the scale. Rather, the results suggest that, since the subjects awakened spontaneously, they had slept enough and were at an arousal level "suitable" for awakening. The reason for the supposedly inferior day sleep being "enough" may probably be sought in the very pronounced circadian rhythm of sleep, as well as the parallel rhythm of alertness (4, 5). Possibly, the arousal effects of sleep restitution and circadian rhythmicity combine to form a total level of arousal. Less sleep would thus be required during the day for the threshold for awakening to be reached. Apparently, the effects of the short sleep appear later, when recuperation wears off and circadian alertness decreases — the "global" estimates of sleep quality seem to suggest such effects (4, 7, 14). Interestingly the significant correlations between the ratings made after the night sleep and stage 4 sleep agree with observations of several other studies (9, 19, 21). This result is, however, somewhat disturbed by a lack of such a correlation for day sleep, for which a correlation with stage 4 instead was obtained for presleep sleepiness.

Even if the age in our group of young subjects was well above adolescence or "student age," the group still slept better during the day than the older group. This observation does support the questionnaire studies of Åkerstedt & Torsvall (7) and Foret et al (12). The differences between the two age groups could possibly have been greater, had the young subjects been closer to adolescence (6). As yet, we do not know the reason for the day sleep difficulties of the older subjects, but we have suggested elsewhere that increased morningness (20) may contribute.

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