*Sleep*, 20(3):215–223


# Morning Work: Effects of Early Rising on Sleep and Alertness

Göran Kecklund, Torbjörn Åkerstedt and Arne Lowden

*National Institute for Psychosocial Factors and Health and Department for Public Health Sciences, Karolinska Institutet, Stockholm, Sweden*

**Summary:** The aim of the present study is to investigate how early morning work affects sleep and alertness. Twenty-two females, employed as airline cabin crew members, participated in the study. The design included two sleep conditions (work day and free day) for an early group and for a control group. The results show that early morning work reduced sleep to 5 hours and 12 minutes and that the reduction of sleep consisted of less stage 2 and rapid eye movement (REM) sleep. However, when the analysis was restricted to the first 5 hours, no differences in sleep stages, arousals, or sleep continuity were obtained between groups or conditions. Analysis of electroencephalogram (EEG) power density for the 0.5–16.5 Hz bands across nonREM periods showed no differences. With respect to the subjective ratings, early morning work was associated with more apprehension of difficulties in awakening and insufficient sleep. Daytime alertness and ease of awakening did not differ between groups, but the early group had significantly more sleepiness and complained more of unrefreshing sleep in connection with the work day compared to the free day. Ratings of insufficient sleep and high daytime sleepiness were mainly predicted (multiple regression analyses) by short total sleep time (TST), whereas apprehension of an unpleasant awakening was predicted by an early wake-up time. It was concluded that early morning work causes a reduction of sleep time and an increase in apprehension stress. **Key Words:** EEG—Alertness—Shift work—Subjective sleep quality—Stress.

Several studies using polysomnography have demonstrated that night shift work interferes with the ensuing day sleep (1–5). The main effect is a 2–4-hour loss of total sleep time (TST) and, in particular, stage 2 and REM sleep. Only two studies have focused on the effects of the early morning shift (4,5). They found that TST is reduced to approximately 5 hours, similar to the day sleep after a night shift. Furthermore, the morning shift was associated with the lowest amount of slow-wave sleep (SWS) and complaints of difficulties in awakening and unrefreshing sleep in one of the studies (5).

The difficulties of early awakening raise the possibility that it has a "retroactive" effect on prior sleep quality through anticipation. We have, for example, found a relation between apprehension of unpleasant awakenings (due to alarms) and reduced SWS in engineers sleeping on call (6). Furthermore, it is likely that the reduction of TST after early rising might be associated with increased daytime sleepiness, although this has not been demonstrated. The present study sought to extend the previous knowledge on the effects of early rising on sleep by specifically focusing on a situation with a sudden introduction of early work shifts and with relatively long commuting time, which adds to the burden of early rising. In particular, interest was focused on sleep continuity, sleep content, difficulty awakening, and other subjective aspects of sleep, as well as subjective sleepiness.

## METHOD

### Subjects and design

Thirty-four randomly selected cabin crew members were asked to participate in the study. The selection was made from the cabin crew scheduling list for short-haul domestic (Sweden) and European flights. Three selection criteria were used: 1) the subjects must live within the Stockholm area, 2) they must start their first duty earlier than 0630 hours, in the case of the early group, or 3) later than 0830 hours, in the case of the control (late) group. Four subjects abstained from participation and six subjects filled out the questionnaire and a diary but could not fit the intensive study into their schedule. Of the remaining 24 subjects (71% of the sample) that participated, two had to be excluded due to loss of electroencephalogram (EEG) data (technical failures). Thus, the present study included 22 females with complete data.

Accepted for publication January 1997.
Address correspondence and reprint requests to Göran Kecklund, IPM, Box 230, 171 77 Stockholm, Sweden.

The scheduling was too variable to permit studying all subjects under all three conditions (early work day, late work day, and free day). Instead, two groups were formed, one early and one control (late) group, and the design of the study involved two conditions: sleep prior to a work day (early or late) and sleep prior to a free day. Twelve subjects belonged to the early group, and 10 subjects belonged to the control group. Two subjects in the early group sometimes worked at night during long-haul flights, whereas the schedules of the others mainly included morning, day, and evening work. The early group was significantly older than the control group (early, 40.6 ± 2.4 years; control, 33.3 ± 1.8 years; $t$ test, 2.4, $p < 0.05$, df = 20). More details on the background factors of the groups are presented in the Results section.

Sleep was polysomnographically recorded in the subjects' homes. The recording of sleep prior to a work day involved the first sleep episode (with two exceptions) of a work spell of three to five work periods. It was expected that the first work shift would involve the most sleep difficulties. Because the first sleep episode prior to the work spell was studied, the risk for carryover effects from the preceding work days was reduced. The sleep recording prior to the free day avoided (with one exception) the first sleep episode of the free time period, because this sleep episode could be affected by a cumulative sleep deficit. The sleep conditions were recorded in a balanced order in both groups.

The study was conducted between March 1991 and January 1992, with a break in data collection between June and September. One week before the first polysomnographic recording, the subjects were visited by an experimenter who explained the study and the sleep recording procedure. The participants were instructed to follow their normal habits during the evening and when going to bed. The subjects were also instructed to avoid hard physical work during the evening prior to the recording and to refrain from alcohol at least 24 hours before the sleep recording. They also started to maintain a sleep–wake diary and to wear an actigraph at least 1 day before the sleep recording. The second sleep recording was made within 2 weeks after the initial recording.

### Sleep recordings and subjective ratings

During the evening of the polysomnographic recording, the experimenter arrived at the subject's home at least 2 hours before bedtime. Electrodes were attached for recording the EEG (C3-A2), electrooculogram (EOG; oblique derivation), electromyogram (EMG; submental), and reference (left mastoid). The recordings were made on four-channel Medilog tape recorders (frequency response = 0.5–100 Hz, filter settings = 0.5 and 75 Hz for high-pass and low-pass filters, respectively).

The experimenter left 1 hour before bedtime to permit the subject to retire spontaneouosly. At bedtime, the subjects, using a visual analog scale, rated "apprehension of difficulties awakening": "What do you think it will be like to wake up?", with 0, very easy, to 100, very difficult. After the final awakening, the subjects removed the electrodes themselves and completed the Karolinska sleep diary [KSD (7)]. The KSD has been validated against polysomnography and showed significant correlations with objective sleep parameters (8). Four questions of the KSD formed a sleep quality index (phrased "How was your sleep?", "ease falling asleep", "calm sleep", and "slept throughout"). The diary also included ratings of "ease awakening" and whether sleep was refreshing (phrased as "well rested"). The response alternatives ranged from 1 (very difficult, very poor, or not rested at all) to 5 (very easy, very good, or completely rested). Also, a new item, "sufficient sleep", was added: "Did you get enough sleep?" (5, yes, definitely enough; 4, yes, almost enough; 3, no, somewhat too little; 2, no, much too little; and 1, no, definitely too little). The subjects also reported whether the awakening was spontaneous or caused by an alarm arrangement (clock, call, etc.).

During the day after the sleep recording, ratings of alertness and sleepiness were made at six times (at wake-up, at 1000, 1400, 1800, and 2000 hours, and at bedtime) using the Karolinska sleepiness scale (KSS). This scale is a nine-point verbally anchored scale with the following steps: 1, very alert; 3, alert; 5, neither alert nor sleepy; 7, sleepy, but no problem staying awake; and 9, very sleepy, effort to stay awake (9). The intermediate steps are not verbally anchored. KSS has been validated against physiological measures of sleepiness (9) and performance tests (10) with good results. The subjects also rated stress (1, very low stress; 3, low stress; 5, neither low nor high stress; 7, high stress; and 9, very high stress) at four times (1000, 1400, 1800, and 2000 hours) during the day and reported how much coffee they had consumed. The subjects also completed the diurnal type scale (11; 1, extreme eveningness, to 4, extreme morningness) and rated their habitual travel time to work and their sleep need.

The electrophysiological recordings were scored in 30-second epochs according to the rules of Rechtschaffen and Kales (12). An awakening was scored if >50% of the epoch included wake time. Also, brief EEG arousals, characterized by abrupt changes in EEG frequency (suggestive of an awake state) and brief increases in EMG amplitude, were scored according to the rules

of the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association (13) to examine the spontaneous fragmentation (interruptions) of the sleep recordings. From the scoring was extracted the number of arousals and the total number of minutes spent in uninterrupted segments of sleep lasting at least 3, 6, or 10 minutes (labeled $TST_3$, $TST_6$, and $TST_{10}$, respectively). The choice of the sleep segment levels is based on data from sleep fragmentation studies indicating that sleep segments should be longer than 10 minutes for succesful recuperation (14–16).

The EEG was also subjected to spectral analysis using a fast Fourier transform (FFT). The minutes scored as stage 0, movement (artifact), or as containing an arousal were removed from the analysis. For the spectral analysis, the EEG was sampled at 64 Hz with conventional filter settings (band pass 0.35–70 Hz). The FFT analysis was based on 4-second epochs with power density integrated across the 0.5–2.5 Hz band (delta I), 2.5–4.5 Hz band (delta II), 4.5–7.5 Hz band (theta), 7.5–12.5 Hz band (alpha), and 13.5–16.5 Hz band (sigma). These 4-second epochs were averaged to form 1-minute means. The latter were averaged across nonREM (NREM) sleep cycles. The value per cycle was standardized according to the mean level of the free day condition (which served as a baseline) for all bands, respectively. The accumulated delta power density (slow-wave energy, SWE) during NREM was calculated as a measure of the recuperation of the entire sleep episode. The SWE during the free day condition was set to 100%, and the work day condition was expressed relative to this condition.

### Statistics

For statistical testing, two- or three-factor analysis of variance (ANOVA) was used (between factor: early vs. control; within factors: work day vs. free day and, where appropriate, time of day or NREM period). When the within factor was a repeated measurement and included more than two levels, the p values were corrected for lack of compound symmetry using the epsilon correction according to the Huyhn-Feldt procedure. However, for clarity, the unadjusted degrees of freedom are given in the text. For tests of the relations between variables, simple and partial correlation coefficients were calculated and stepwise multiple regression analyses were performed. The alpha level was set to 0.05.

## RESULTS

The groups were compared with respect to background factors using two-tailed $t$ tests. Except for the age difference (see the Methods section), the groups did not differ with respect to diurnal type (1 eveningness–4 morningness, means ± standard error; early: 2.3 ± 0.2, control: 2.0 ± 0.1), travel time to work (early: 60 ± 4.8 minutes, control: 68 ± 5.4 minutes), or self-rated sleep need (early: 8.3 ± 0.3 hours, control: 8.0 ± 0.3 hours). The work day (check-in) started at 06.15 ± 0.1 hours for the early group and at 12.54 ± 0.2 hours for the control group ($t = 7.5$, $p < 0.001$, $df = 20$) and ended at 14.00 ± 0.3 hours for the early group and at 20.35 ± 0.3 hours for the control group ($t = 7.1$, $p < 0.001$, $df = 20$). The length of the duty period did not differ between groups (early: 7.7 ± 0.3 hours, control: 7.6 ± 0.3 hours, $t = 0.4$, ns).

Data on sleep timing are presented in Table 1. For the wake-up time, all effects were significant (Table 1), whereas for bedtime there was no significant interaction. The significant group effect indicated that the early group had earlier bedtimes than the control group. Both groups showed earlier bedtimes for the work day, although the difference was most clear for the early group. The wake-up time on the work day occurred more than 3 hours earlier for the early group compared to the control group, and approximately 2.5 hours earlier compared to the free day. The wake-up time of the control group occurred 30 minutes earlier during the work day compared to the free day. Prior time awake before bedtime showed no significant effects.

The sleep ratings are presented in Table 1. The apprehension of the awakening showed a significant interaction, indicating that the early group foresaw relatively more difficulties awakening on the work day, whereas there was no group difference on the free day. The rated sleep quality index, ease of awakening, and alertness according to KSS at wake-up showed no significant effects. The early morning work yielded relatively more complaints of insufficient sleep, as indicated by the significant interaction. The rating of refreshed sleep (well rested) showed a significant effect of sleep condition. Thus, both groups had more unrefreshing sleep in connection with the work day. When the rating of refreshed sleep was tested ($t$ test) within each group, only the early group showed a significant difference between the work day and the free day ($t = 2.3$, $p < 0.05$, $df = 11$; control group, $t = 0.9$, ns).

Reported spontaneous awakening (yes/no) showed a significant group difference for the work day condition ($x^2 = 4.8$, $p < 0.05$, $df = 1$). Only one subject had a spontaneous awakening in the early group, whereas five subjects woke up spontaneously in the control group. There was no difference between the groups for the free day (spontaneous awakening: early = six subjects, control = six subjects). The mean daytime stress ratings (on the subsequent day; see Table 1) showed

**TABLE 1.** *Means, standard error, and ANOVA results for the ratings and the sleep score variables (df = 1/20)*

| | Early group | | Control group | | *F* ratios/two-way ANOVA | | |
|---|---|---|---|---|---|---|---|
| | Free day | Work day | Free day | Work day | Group | Free/Work | Gr × F/W |
| Apprehension before sleep (0 low–100 max) | 28 ± 7.0 | 58 ± 8.3 | 22 ± 6.0 | 25 ± 5.8 | 6.9* | 10.1** | 7.1* |
| Sleep quality index (1 low–5 high) | 3.6 ± 0.3 | 3.6 ± 0.3 | 3.8 ± 0.3 | 4.0 ± 0.3 | 1.3 | 0.1 | 0.2 |
| Sufficient sleep (1 min–5 max) | 3.3 ± 0.1 | 2.2 ± 0.3 | 3.3 ± 0.3 | 3.2 ± 0.4 | 2.1 | 7.0* | 4.8* |
| Refreshing sleep (1 min–5 max) | 3.0 ± 0.2 | 2.2 ± 0.2 | 3.2 ± 0.4 | 2.8 ± 0.3 | 1.5 | 5.2* | 0.6 |
| Ease awakening (1 min–5 max) | 3.2 ± 0.2 | 2.8 ± 0.3 | 3.5 ± 0.4 | 2.9 ± 0.3 | 0.6 | 2.4 | 0.1 |
| KSS at wake-up (1 min–9 max) | 5.7 ± 0.6 | 6.8 ± 0.5 | 5.2 ± 0.7 | 5.7 ± 0.8 | 1.6 | 1.9 | 0.3 |
| Stress subsequent day (1 min–9 max) | 2.3 ± 0.4 | 3.4 ± 0.3 | 1.9 ± 0.4 | 3.6 ± 0.5 | 0.8 | 28.4*** | 1.1 |
| No. of cups of coffee (subsequent day) | 2.2 ± 0.4 | 2.7 ± 0.3 | 2.4 ± 1.0 | 2.4 ± 0.9 | 0.0 | 1.3 | 1.0 |
| Prior time awake (hours) | 16.1 ± 0.2 | 14.8 ± 0.3 | 15.4 ± 0.5 | 15.7 ± 0.6 | 0.2 | 1.9 | 3.2 |
| Bedtime (hours and minutes) | 23.04 ± 19 | 22.16 ± 10 | 23.40 ± 22 | 23.13 ± 19 | 5.4* | 6.7* | 0.5 |
| Wake-up time (hours and minutes) | 06.56 ± 24 | 04.13 ± 7 | 07.50 ± 21 | 07.22 ± 23 | 27.0*** | 39.8*** | 27.0*** |
| TIB, (minutes) | 472 ± 19 | 357 ± 11 | 490 ± 28 | 489 ± 25 | 9.5** | 13.6*** | 11.0** |
| TST (minutes) | 427 ± 16 | 312 ± 17 | 442 ± 24 | 450 ± 22 | 11.3** | 12.9** | 13.9*** |
| $TST_3$ (minutes) | 414 ± 16 | 301 ± 19 | 428 ± 23 | 438 ± 22 | 10.5** | 13.0** | 14.3*** |
| $TST_6$ (minutes) | 391 ± 19 | 289 ± 19 | 401 ± 19 | 409 ± 21 | 8.3* | 10.0** | 11.1** |
| $TST_{10}$ (minutes) | 363 ± 19 | 269 ± 21 | 372 ± 20 | 377 ± 20 | 6.0* | 10.4** | 10.3** |
| Sleep latency (minutes) | 16 ± 3.4 | 21 ± 6.1 | 14 ± 4.5 | 12 ± 1.6 | 0.9 | 0.5 | 1.8 |
| Latency REM (minutes) | 68 ± 4.1 | 72 ± 10.1 | 71 ± 7.2 | 74 ± 6.4 | 0.1 | 0.2 | 0.0 |
| % Sleep efficiency | 90.7 ± 0.7 | 86.8 ± 3.7 | 90.4 ± 1.7 | 92.2 ± 1.0 | 1.2 | 0.3 | 1.6 |
| No. of awakenings/hour | 1.2 ± 0.2 | 1.1 ± 0.1 | 1.1 ± 0.1 | 1.1 ± 0.1 | 0.1 | 0.0 | 0.7 |
| No. of arousals/hour | 3.8 ± 0.4 | 4.0 ± 0.6 | 3.9 ± 0.4 | 3.8 ± 0.3 | 0.0 | 0.0 | 0.5 |
| Stage 0 (minutes) | 23 ± 5.8 | 18 ± 9.4 | 28 ± 8.2 | 21 ± 5.2 | 0.3 | 0.5 | 0.0 |
| Stage 1 (minutes) | 11 ± 4.3 | 8 ± 1.7 | 7 ± 1.7 | 10 ± 2.4 | 0.1 | 0.0 | 1.9 |
| Stage 2 (minutes) | 218 ± 13 | 165 ± 9 | 241 ± 18 | 240 ± 15 | 10.1** | 5.7* | 4.7* |
| Stage 3 (minutes) | 18 ± 2.5 | 17 ± 3.6 | 18 ± 2.0 | 16 ± 1.8 | 0.1 | 0.8 | 0.0 |
| Stage 4 (minutes) | 63 ± 8.3 | 53 ± 6.9 | 57 ± 5.2 | 61 ± 6.8 | 0.0 | 0.7 | 2.2 |
| SWS (minutes) | 82 ± 8.2 | 70 ± 7.9 | 75 ± 5.9 | 77 ± 6.5 | 0.0 | 1.0 | 1.6 |
| SWS (% TST) | 19 ± 1.7 | 21 ± 2.0 | 17 ± 1.8 | 17 ± 2.0 | 1.5 | 0.7 | 0.4 |
| REM (minutes) | 115 ± 5 | 71 ± 6 | 119 ± 11 | 122 ± 13 | 7.1* | 11.1* | 11.5** |
| REM (% TST) | 27 ± 1.0 | 22 ± 1.0 | 26 ± 2.0 | 27 ± 2.0 | 1.4 | 0.7 | 4.6* |
| Movement (minutes) | 7.0 ± 0.8 | 5.2 ± 0.6 | 6.2 ± 0.8 | 6.1 ± 0.7 | 0.0 | 3.9 | 2.4 |
| SWE (% of free day) | 100 ± 0 | 87.7 ± 10 | 100 ± 0 | 98.9 ± 8 | | (see text) | |

ANOVA, analysis of variance; KSS, Karolinska sleepiness scale; TIB, time in bed; TST, total sleep time; REM, rapid eye movement; SWS, slow-wave sleep; SWE, slow-wave energy; min, minimum; max, maixmum.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

significantly higher stress on work days compared to free days but no difference between the groups. Coffee consumption during the subsequent day did not differ between groups or between conditions.

The results of the EEG variables are listed in Table 1. The time in bed (TIB), total sleep time (TST), all sleep segment measures ($TST_{3,6,10}$), stage 2 sleep, and REM sleep showed significant effects of group, condition, and interaction (only interaction for REM%). For the other sleep stage variables, no significant effects were found. SWE was analyzed by single-group *t* tests in which workday sleep was compared with free-day sleep. The *t* values were, however, insignificant. The sleep stage data were also analyzed using only the first 5 hours of the TIB (the shortest TIB in the early sleep condition was 5 hours), and no significant effects were found.

The results of the power density per nonREM period (NREMP) are presented in Table 2. Three-way ANOVAs (factors: group, sleep condition, and NREMP) were computed for each band, respectively. The analyses were restricted to the first two NREMP because some sleep episodes in the early morning condition included only two complete NREMPs. However, the mean for the third NREMP is presented in the table. The ANOVAs showed no significant main effect of group ($F < 0.6$, ns) or sleep condition ($F < 1.0$, ns) for any of the bands. The delta II ($F = 53.9$, $p < 0.001$, df = 1/20) and theta bands ($F = 7.7$, $p < 0.05$, df = 1/20) did show significant NREMP effects—a lower power density was found in the second NREMP. For the other bands, no significant main effect of NREMP was found ($F < 3.9$, ns). None of the interactions showed a statistically reliable effect ($F < 3.9$, ns).

The results of the alertness and sleepiness ratings (KSS) at five times of day are presented in Fig. 1. The ratings were tested by a three factor ANOVA (factors: group, sleep condition, and time of day). Time of day ($F = 21.9$, $p < 0.001$, df = 4/80) and sleep condition ($F = 9.6$, $p < 0.01$, df = 1/20) showed significant effects, whereas the group factor was insignificant (*F*

**TABLE 2.** *Means and standard error for power density across nonREM (NREM) cycles (relative to the mean for the free day)*

| | Free day | | | Work day | | |
|---|---|---|---|---|---|---|
| | NREM 1 | NREM 2 | NREM 3 | NREM 1 | NREM 2 | NREM 3[a] |
| Delta I | | | | | | |
| Early | 124 ± 9 | 123 ± 9 | 94 ± 8 | 123 ± 13 | 140 ± 13 | 95 ± 12 |
| Control | 125 ± 15 | 110 ± 12 | 87 ± 11 | 132 ± 9 | 121 ± 16 | 82 ± 7 |
| Delta II | | | | | | |
| Early | 133 ± 5 | 110 ± 4 | 93 ± 4 | 137 ± 13 | 118 ± 10 | 94 ± 8 |
| Control | 141 ± 9 | 111 ± 5 | 95 ± 5 | 150 ± 19 | 115 ± 13 | 103 ± 16 |
| Theta | | | | | | |
| Early | 122 ± 4 | 105 ± 3 | 97 ± 2 | 122 ± 11 | 112 ± 10 | 97 ± 8 |
| Control | 120 ± 13 | 112 ± 5 | 101 ± 5 | 134 ± 9 | 114 ± 9 | 101 ± 9 |
| Alpha | | | | | | |
| Early | 117 ± 7 | 99 ± 2 | 99 ± 2 | 112 ± 12 | 100 ± 10 | 97 ± 8 |
| Control | 112 ± 7 | 106 ± 4 | 95 ± 3 | 116 ± 5 | 111 ± 10 | 106 ± 13 |
| Sigma | | | | | | |
| Early | 109 ± 6 | 90 ± 3 | 94 ± 4 | 110 ± 13 | 99 ± 10 | 104 ± 12 |
| Control | 98 ± 7 | 96 ± 6 | 100 ± 5 | 107 ± 16 | 112 ± 16 | 126 ± 19 |

[a] Includes 11 subjects for the early group.

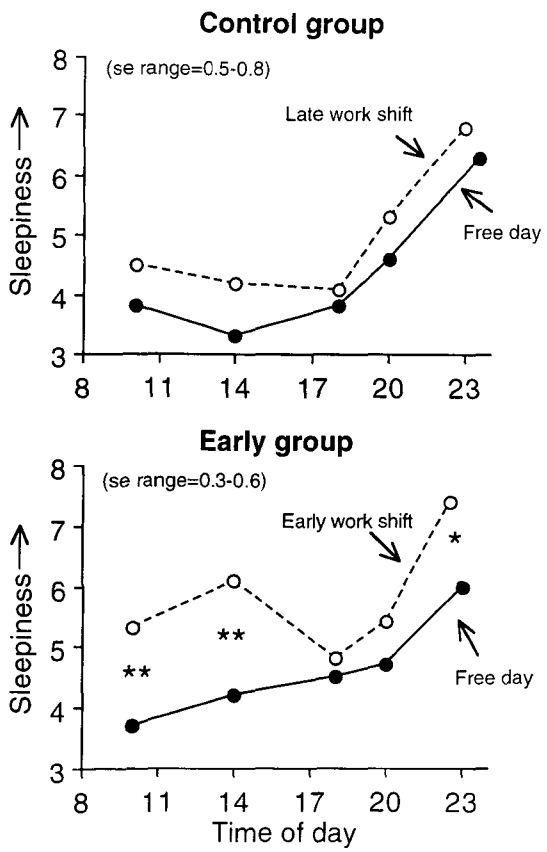


**FIG. 1.** Mean ratings of sleepiness according to the Karolinska sleepiness scale at five times of the day. Asterisks indicate significant pairwise testing (after significant overall $F$ ratio) with planned orthogonal contrasts. *$p < 0.05$, **$p < 0.01$ [the range of the standard error (se) of the means is presented in each figure].

= 1.3, ns, df = 1/20). Thus, sleepiness increased during the day and was lower during the free day. None of the interactions were significant ($F < 1.6$, ns). To test if the difference between workday and day off was statistically reliable in both groups, we also performed a two-way ANOVA with sleep condition and time of day as main factors for each group, respectively. For the early group a significant main effect of sleep condition was found ($F = 7.5$, $p < 0.05$, df = 1/10), whereas this effect was insignificant for the control group ($F = 2.8$, ns, df = 1/8). Both groups showed a significant variation with time of day ($F > 8.6$, $p < 0.001$) but insignificant interactions ($F < 1.7$, ns). For the early group, planned orthogonal contrasts were calculated to test for differences between the workday and the free day for each time point. This analysis showed significantly higher sleepiness on the work day at 1000 and 1400 hours and at bedtime (see Fig. 1). The sleepiness ratings were also tested with a separate two-factor ANOVA for the work day (factors: group and time of day). However, no difference was found between the groups ($F = 2.5$, ns, df = 1/20).

To understand more about the possible causes of the response to early morning work, we performed a series of analyses on the relation between the key variables showing negative effects: apprehension of difficulties awakening, sufficient sleep, TST and daytime sleepiness (KSS mean for the work day: 5.4 ± 0.3; five data points per subject), and possible predictors on the other. First, conventional correlations were carried out (Table 3; the work day condition was used for both groups, n = 22). The key variables were correlated with most of the variables in Table 1. The sleep segment variables correlated strongly with TST ($r > 0.93$)

**TABLE 3.** *Correlations (r) and partial correlations (partial r, keeping wake-up time constant) between dependent variables and subjective and physiological sleep variables*

| | Apprenehnsion of awakening[a] (r/partial r) | Sufficient sleep[b] (r/partial r) | Mean daytime sleepiness[c] (r/partial r) | Total sleep time (r/partial r) |
|---|---|---|---|---|
| Age | 0.56*/0.25 | −0.60**/0.04 | 0.38/−0.16 | −0.76***/−0.57** |
| DTS (1 eveningness–4 morningness) | −0.24/−0.60** | 0.21/0.48* | −0.19/−0.38 | 0.15/0.68** |
| Prior time awake | −0.16/−0.20 | 0.24/−0.36 | −0.31/0.09 | 0.21/−0.16 |
| Sleep quality index (1 low–5 high) | −0.49*/−0.43 | 0.47*/0.40 | −0.23/−0.11 | 0.39/0.31 |
| Refreshing sleep (1 min–5 max) | −0.57**/−0.35 | 0.89***/0.85*** | −0.72***/−0.62** | 0.66**/0.51* |
| Ease awakening (1 min–5 max) | −0.46*/−0.47* | 0.43*/0.41 | −0.27/−0.21 | 0.36/0.39 |
| Sufficient sleep (1 min–5 max) | −0.59**/−0.29 | — | −0.81***/−0.74*** | 0.71***/0.45* |
| Apprehension (0 low–100 max) | — | −0.59**/−0.29 | 0.46*/0.17 | −0.69***/−0.27 |
| Spontaneous awakening (0 no, 1 yes) | −0.31/0.12 | 0.45*/0.18 | 0.28/−0.01 | 0.35/−0.21 |
| Bedtime | −0.19/0.27 | 0.06/−0.39 | −0.17/0.12 | 0.10/−0.73*** |
| Wake-up time | −0.70***/− | 0.62**− | −0.51*/− | 0.84**/− |
| TST | −0.69***/−0.27 | 0.71***/0.45* | −0.58**/−0.33 | — |
| No. of awakenings | −0.36/−0.04 | 0.18/−0.24 | −0.11/0.24 | 0.64**/0.39 |
| Sleep latency | 0.03/−0.14 | −0.17/−0.08 | 0.09/0.00 | −0.25/−0.17 |
| Sleep efficiency | −0.26/−0.08 | 0.43*/0.34 | −0.42/−0.33 | 0.56*/0.62** |
| Stage 0 + 1 + M (minutes) | 0.03/0.08 | −0.28/−0.39 | 0.41/0.50* | −0.21/−0.46* |
| Stage 0 + 1 + M (% TST) | 0.03/0.11 | −0.38/−0.32 | 0.43*/0.38 | −0.49*/−0.57** |
| Stage 2 (minutes) | −0.54**/−0.04 | 0.59**/0.25 | −0.55**/−0.30 | 0.90***/0.76*** |
| Stage 2 (% TST) | 0.33/0.35 | 0.17/−0.13 | 0.02/−0.05 | −0.14/−0.08 |
| Slow-wave sleep (minutes) | −0.44*/−0.40 | 0.33/0.24 | −0.19/−0.08 | 0.42/0.41 |
| Slow-wave sleep (% TST) | −0.05/−0.35 | −0.13/0.07 | 0.18/0.04 | −0.22/0.06 |
| REM (minutes) | −0.60**/−0.08 | 0.71***0.45* | −0.58**/−0.33 | 0.87***/0.60** |
| REM (% TST) | −0.40/−0.01 | 0.55**/0.31 | −0.53*/−0.27 | 0.62**/0.32 |

DTS, diurnal type scale; TST, total sleep time; REM, rapid eye movement; min, minimum; max, maximum.
For simple correlations (r), df = 20; for partial correlations, df = 19.
[a] 0 low–100 maximum.
[b] 1 definitely too little–5 definitely enough.
[c] Karolinska sleepiness scale: 1 very alert–9 very sleepy.
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

and were therefore excluded. However, because time of wake-up determined much of the variance in several of the predictors, partial correlations were also calculated to account for wake-up time.

Apprehension of difficulties awakening was associated positively with age and negatively with subjective sleep quality, refreshing sleep, ease awakening, rating of sufficient sleep, early wake-up time, short TST, and low amounts of stage 2, SWS, and REM sleep, but not when stage 2, SWS, and REM sleep were expressed as percent of TST. However, the partial correlations (keeping wake-up time constant) showed that only ease awakening remained significant and that diurnal type (DTS) became significant.

The rating of sufficient sleep was associated with lower age, a higher sleep quality index, ease awakening, refreshing sleep, low apprehension, spontaneous awakening, late wake-up time, long TST, high sleep efficiency, and a high amount of stage 2 (not for percent of TST) and REM sleep, respectively. The partial correlations mainly showed that refreshed sleep, TST, and the absolute amount of REM remained significant and that DTS (morningness) became significant.

High daytime sleepiness was associated with unrefreshing sleep, insufficient sleep, apprehension of difficulties awakening, early wake-up, short TST, high percentages of stages 0, 1, and M, and low amounts of stage 2 (not percent stage 2) and REM sleep. The partial correlations showed that insufficient sleep and unrefreshed sleep remained significant and that the absolute amount of stage 0 + 1 + M became significant, with a high amount of "light" sleep and wake time associated with more sleepiness.

Long TST was associated with lower age, refreshing sleep, sufficient sleep, low apprehension, late wake-up time, high number of awakenings, high sleep efficiency, low relative amount (percent) of stage 0 + 1 + M, and high amount of stage 2 and REM sleep (only the absolute amount for stage 2). The partial correlations showed that age, refreshed sleep, sufficient sleep, sleep efficiency, stage 0 + 1 + M, and stage 2 and REM sleep remained significant and that DST (morningness = longer TST) became significant.

To understand which combination of variables would predict the key dependent variables, stepwise multiple regression analyses (MRA; Table 4) were performed. The variables used to predict apprehension and TST were age, DTS, prior time awake, bedtime, and wake-up time. The significant predictors of apprehension became time of wake-up and DTS (explained

**TABLE 4.** *Stepwise multiple regression analysis*

| Dependent variable | Significant predictors | Beta | $R^2_{change}$ (%) | *F* ratio | p value | df |
|---|---|---|---|---|---|---|
| Apprehension | Wake-up time | −0.80 | +49 | 19.2 | <0.001 | 2/19 |
| | DTS | −0.44 | +18 | | | |
| Sufficient sleep | TST | 0.71 | +51 | 20.4 | <0.001 | 1/20 |
| Mean daytime sleepiness[a] | Sufficient sleep | −0.81 | +66 | 39.0 | <0.001 | 1/20 |
| | (sufficient sleep removed) | | | | | |
| | TST | −0.55 | +34 | 7.5 | <0.01 | 2/19 |
| | No. of awakenings | 0.32 | +10 | | | |
| TST | Wake-up time | 0.93 | +71 | 54.6 | <0.001 | 4/17 |
| | Bedtime | −0.30 | +16 | | | |
| | Age | −0.19 | +4 | | | |
| | DTS | 0.19 | +2 | | | |
| | (wake-up time removed) | | | | | |
| | Age | −0.76 | +57 | 20.8 | <0.001 | 1/20 |

DTS, diurnal type scale; TST, total sleep time.

Table includes the significant predictor(s) (see text for description of predictors), the corresponding beta (standardized) coefficient for the last step, the $R^2_{change}$ value for each significant step, and the *F* statistics for the last step.

[a] Karolinska sleepiness scale.

variance = 67%). Increased apprehension was associated with early rising and eveningness. TST was predicted by time of wake-up, bedtime, age, and DTS (explained variance = 93%). Long sleep was associated with a late rising, early bedtime, low age, and morningness. However, when wake-up time was removed from the analysis, only age remained significant.

The MRA for the rating of sufficient sleep used the previous predictors, plus TST, number of awakenings per hour, sleep latency, sleep efficiency, stage 0 + 1 + M, and percent values of stage 2, SWS, and REM sleep. To avoid multicollinearity (due to high correlations with TST), the percent values of stage 2, SWS, and REM sleep were considered more appropriate than the absolute values expressed in minutes. Sufficient sleep was predicted by TST; short sleep was associated with increased insufficiency. For the MRA against daytime sleepiness, the ratings of ease awakening, sufficient sleep, sleep quality, spontaneous awakening, and refreshed sleep were added as predictors. The analysis showed that rated sufficient sleep was the significant (negative) predictor. When the subjective sleep ratings were removed from the analysis, TST and number of awakenings became the significant predictors ($R^2$ = 44%). A short sleep and a high number of awakenings were associated with a high level of sleepiness.

## DISCUSSION

Early morning work reduced sleep by almost 2 hours and involved less stage 2 and REM sleep. The results replicate the findings of other EEG studies of sleep and early morning work (4,5). However, no significant effects were found for the other sleep stage related variables, power density in the 0.5–16.5 Hz bands, sleep continuity measures based on segments of uninterrupted sleep, or the occurrence of microarousals. The subjective ratings of sleep quality, ease awakening, and refreshing sleep did not differ between the conditions, and only the rating of sufficient sleep was negatively influenced by the early morning work. Neither did ratings of alertness or sleepiness and stress increase significantly for early morning work. However, the alertness ratings and the rating of refreshing sleep were significantly worse in connection with the workday, regardless of time of wake-up, compared to the free day. The differences in sleepiness and refreshing sleep between the workday and the free day were significant for the early group only. This suggests increased sleepiness and less refreshing sleep in connection with early morning work.

The shortening of sleep was due to the 3-hour advance of rising and the lack of a sufficiently compensating advance of bedtime (only 1 hour). Sleep latency, time awake after sleep onset, and premature awakening were clearly not involved in the sleep reduction. The modest effect of early morning work on the temporal position of the bedtime has been previously observed (4,5,17). One reason for the lack of phase advance may be the low physiological sleep tendency during the evening (18,19,20). Another reason maybe that most subjects give priority to social activities rather than going to bed earlier (4,17,21).

The expected association between early morning rising and apprehension of difficulties awakening was confirmed. Not surprisingly, apprehension showed a strong correlation (r = −0.70) with wake-up time. The reason for the apprehension is probably the difficulty in terminating sleep at the circadian trough (20,22), and there is a clear avoidance of this time for spon-

taneous sleep termination (23–25). The finding of an association between apprehension difficulties and "eveningness" supports the idea that the circadian phase plays an important role in the anticipation of the awakening. The correlation between apprehension and subjective, or poor, sleep ratings, short TST, and short SWS could imply an impairment effect of apprehension. However, when the effect of wake-up time was kept constant by partial correlation analyses, TST and SWS were no longer significant, and only the association with ease of awakening remained significant. This suggests that the apprehension of difficulties waking up is linked mainly to the wake-up time per se, and it is unclear whether there is any relation to sleep content.

Interestingly, the rating of ease of awakening did not show a significant effect of early rising, whereas the apprehension of the difficulties awakening did differ. The reason is not clear but could be due to the relatively early rising on the free day for the early group (reducing the difference in timing between the conditions). Possibly, there might also have been arousal effects from the anticipation, reducing the difficulties awakening.

The number of significant differences between the early and control groups were fewer compared to our previous study (5). Thus, the previously obtained reduction of SWS and the increased discomfort at the awakening were not replicated. Possibly, the present between-group design may have made significant differences more difficult to obtain because of a lower statistical power. Thus, a larger sample size of the present study may have also detected minor differences between the conditions. Another reason for the lack of effects may be related to the age difference between the groups: the early group was 8 years older than the control group. Theoretically, the higher age for the early group may be associated with a phase advance, which would make it easier to tolerate early rising. On the other hand, the groups did not differ with respect to diurnal type (morningness or eveningness). However, the early group showed a moderate advance of bedtime (circa 30 minutes) and wake-up time (circa 1 hour) for the free day condition compared to the control group. This small difference may indicate that there was a group difference for circadian phase. Finally, the present study involved only females, whereas the previous studies involved males. Thus, gender differences cannot be excluded and need to be further examined.

Although the feelings of insufficient sleep and lack of alertness during daytime are common sleep complaints in society, almost no field studies have examined how these variables relate to physiological sleep. The large interindividual variation of the present data offered an opportunity to explore the covariation between these variables and subjective and objective sleep variables. One finding was that the rating of sufficient sleep was strongly associated with the TST variables, or variables related to TST, like stage 2 and REM sleep. Although wake-up time correlated with the rating of sufficient sleep, it did not enter the multiple regression. However, when wake-up time was controlled (partial correlations), the association between the ratings and TST decreased, although it remained significant. Because wake-up time determined much of the variance for TST, the relationship should be interpreted with caution. On the other hand, TST reflects two key components of objective sleep quality, the duration and continuity of sleep, that intuitively would be regarded as important for the recuperative value of sleep. An experimental design is necessary, however, to verify this hypothesis.

Mean daytime sleepiness was more clearly related to wake-up time. When wake-up time was kept constant, the sum of stages 0, 1, and movement time was the only significant objective (polysomnographical) predictor. On the other hand, when no variable was forced into the analysis, TST became the strongest physiological predictor of alertness. However, the subjective ratings of sufficient sleep and refreshing sleep were even stronger predictors of daytime sleepiness and remained significant when wake-up time was controlled. Thus, the feeling immediately after awakening of whether sleep was sufficient and recuperative seems to influence the perception of daytime alertness. The influence of an early wake-up time on sleepiness has been previously observed in laboratory studies (26–28). Also, other studies have observed a relation between fragmented sleep (as reflected in increased frequency of awakenings, much stage 1 sleep, and time awake after sleep onset) and increased sleepiness (14–16,29). The notion that rated insufficiency of sleep is associated with sleepiness agrees with the obvious relation between short sleep and increased sleepiness (21,29). Again, the high intercorrelation between wake-up time and TST suggests caution in interpreting results. Still, the results suggest that subjective daytime sleepiness is mainly related to sleep duration, whereas the variables reflecting the content of sleep (e.g. amount of sleep stages) seem to be less important, at least within the present range of variation for these variables.

In conclusion, the present study shows that early morning work causes a reduction of sleep length and stage 2 and REM sleep, and an increase of apprehension stress, whereas it is still not clear whether early morning work causes reduced alertness or difficulties awakening.

**Acknowledgements:** This study was supported by the Swedish Work Environment Fund and the Scandinavian Airlines System.

## REFERENCES


1. Torsvall L, Åkerstedt T, Gillberg M. Age, sleep and irregular work hours: a field study with EEG recording, catecholamine excretion, and self-ratings. *Scand J Work Environ Health* 1981; 7:196–203.
2. Dahlgren K. Adjustment of circadian rhythms and EEG sleep functions to day and night sleep among permanent night workers and rotating shift workers. *Psychophysiology* 1981;18:381–91.
3. Tepas DI, Walsh JK, Moss PD, Armstrong D. Polysomnographic correlates of shift worker performance in the laboratory. In: Reinberg A, Vieux N, Andlauer P, eds. *Night and shift work: biological and social aspects.* Oxford: Pergamon Press, 1981: 179–86.
4. Tilley AJ, Wilkinson RT, Warren PSG, Watson WB, Drud M. The sleep and performance of shift workers. *Hum Factors* 1982; 24:624–41.
5. Åkerstedt T, Kecklund G, Knutsson A. Spectral analysis of sleep electroencephalography in rotating three-shift work. *Scand J Work Environ Health* 1991;17:330–6.
6. Torsvall L, Åkerstedt T. Disturbed sleep while being on call. An EEG study of apprehension in ships' engineers. *Sleep* 1988;11: 35–8.
7. Åkerstedt T, Hume K, Minors D, Waterhouse J. The subjective meaning of good sleep—an intraindividual approach using the Karolinska Sleep Diary. *Percept Mot Skills* 1994;79:287–96.
8. Åkerstedt T, Hume K, Minors D, Waterhouse J. The meaning of good sleep: a longitudinal study of polysomnography and subjective sleep quality. *J Sleep Res* 1994;3:152–8.
9. Åkerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. *Int J Neurosci* 1990;52:29–37.
10. Gillberg M, Kecklund G, Åkerstedt T. Relations between performance and subjective ratings of sleepiness during a night awake. *Sleep* 1994;17:236–41.
11. Torsvall L, Åkerstedt T. A diurnal type scale. *Scand J Work Environ Health* 1980;6:283–90.
12. Rechtschaffen A, Kales A, eds. *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects.* Bethesda: US Department of Health, Education and Welfare, Public Health Service, 1968.
13. American Sleep Disorders Association. EEG arousals: scoring rules and examples. A preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association. *Sleep* 1992;15:174–84.
14. Bonnet MH. Performance and sleepiness as a function of frequency and placement of sleep disruption. *Psychophysiology* 1986;23:263–71.
15. Stepanski E, Lamphere J, Roehrs T, Zorick F, Roth T. Experimental sleep fragmentation in normal subjects. *Int J Neurosci* 1987;33:207–14.
16. Magee J, Harsh J, Badia P. Effects of experimentally-induced sleep fragmentation on sleep and sleepiness. *Psychophysiology* 1987;24:528–34.
17. Folkard S, Barton J. Does the "forbidden zone" for sleep onset influence morning shift sleep duration? *Ergonomics* 1993;36: 85–91.
18. Lavie P. Ultrashort sleep-waking schedule. III. "Gates" and "forbidden zones" for sleep. *Electroencephalogr Clin Neurophysiol* 1986;63:414–25.
19. Dijk D-J, Czeisler CA. Contribution of the circadian pacemaker and the sleep homeostat to sleep propensity, sleep structure, electroencephalographic slow waves, and sleep spindle activity in humans. *J Neurosci* 1995;15:3526–8.
20. Åkerstedt T, Hume K, Minors D, Waterhouse J. The regulation of sleep and naps on an irregular schedule. *Sleep* 1993;16:736–43.
21. Roehrs T, Zorick F, Sicklesteel J, Wittig R, Roth T. Excessive daytime sleepiness associated with insufficient sleep. *Sleep* 1983;6:319–25.
22. Dinges DF. The influence of the human circadian timekeeping system on sleep. In: Kryger MH, Roth T, Dement WC, eds. *Principles and practice of sleep medicine.* Philadelphia: W.B. Saunders Co., 1989:153–62.
23. Czeisler CA, Weitzman ED, Moore-Ede MC, Zimmerman JC, Knauer RS. Human sleep: its duration and organization depend on its circadian phase. *Science* 1980;210:1264–7.
24. Zulley J, Wever R, Aschoff J. The dependence of onset and duration of sleep on the circadian rhythm of rectal temperature. *Pflügers Arch* 1981;391:314–8.
25. Strogatz SH, Kronauer RE, Czeisler CA. Circadian regulation dominates homeostatic control of sleep length and prior wake length in humans. *Sleep* 1986;9:353–64.
26. Taub JM, Berger RJ. Acute shifts in the sleep-wakefulness cycle: effects on performance and mood. *Psychosom Med* 1974; 36:164–73.
27. Clodoré M, Benoit O, Foret J, et al. Early rising or delayed bedtime: which is better for a short night sleep? *Eur J Appl Physiol* 1987;56:403–11.
28. Gillberg M, Kecklund G, Axelsson J, Åkerstedt T. The effects of a short daytime nap after restricted night sleep. *Sleep* 1996; 19:570–5.
29. Roth T, Roehrs T, Carskadon M, Dement W. Daytime sleepiness and alertness. In: Kryger MH, Roth T, Dement WC, eds. *Principles and practice of sleep medicine.* Philadelphia: W.B. Saunders Co., 1989:14–23.