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Altered Environment and Biological Rhythms

Napping at Home and Alertness on the Job in Rotating Shift Workers

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Summary: Conditions surrounding self-selected napping and its association with waking function were examined in a quasi-experimental study at two worksites with workers on 8- and 12-hour rotating shifts. Nap frequency, sleep quantity, quality and timing were determined from daily questionnaires, and performance/alertness during the workshift was assessed with on-site computerized testing. Results indicated that most napping occurred prior to the first night shift of the week. Napping prior to the first shift supplemented an apparently adequate quantity of main sleep, whereas napping during the workweek compensated for a reduced quantity of main sleep. Sleep quality was rated higher on no-nap days than on nap days and higher prior to the first shift than during the workweek. These results generally support a compensatory view of napping. Worksite performance/alertness testing, however, indicated diminished alertness during the shift on nap days compared to no-nap days, which was not consistent with a compensatory view of napping. Decreased alertness on nap days may have been associated with poorer sleep quality or with differences in circadian rhythm adaptation on those days. **Key Words:** Naps—Shift work—Sleep quality—Worksite alertness.

Napping is a common feature of the human sleep pattern undertaken to replace previously lost sleep, prepare for extended wakefulness, maintain alertness during extended wakefulness or provide enjoyment during idle moments [see Dinges and Broughton (1) for reviews]. Individuals engaged in night or shift work are assumed to nap frequently in an attempt to compensate for inadequate sleep (2). Survey studies confirm that napping is common among shift workers and occurs most frequently in association with night shift (2–4). The pressure to nap is likely to be high in shift workers because night work and inadequate daytime sleep lead to unwanted sleepiness on a regular basis. This pressure can be so extreme that involuntary napping occurs at times when it is ill-advised or prohibited (5,6).

Studies of shift-worker sleep generally support a compensatory view of napping. That is, naps are taken to replace lost sleep or reduce sleepiness. In the case of daytime napping prior to night shift, the main sleep period tends to be shorter in nappers compared to nonnappers, and the nap usually results in total sleep time equivalent to that seen in nonnappers (4,6–11). In the less frequent case of permissible napping during a night shift, naps also were reported to compensate for insufficient daytime sleep (12–15).

The relationship between napping and the rated quality (as opposed to quantity) of the main sleep period has been explored less frequently in shift workers. Survey studies by Tepas and colleagues (11,16,17) suggested that permanent night or rotating shift workers who nap also report more sleep disturbance. On the basis of their results, Tepas and colleagues advised against napping as a sleep strategy for the shift worker. In contrast to their results, however, Härmä et al. (18) observed more sleep disturbance in a nonnapping group, and Chan et al. (7) observed no difference in sleep disturbance in napping versus nonnapping night workers.

In addition to napping effects on sleep, napping is assumed to maintain or enhance waking alertness. Laboratory studies of non-shift workers napping during the day, in supplement to the main sleep period at night, have demonstrated positive effects on both performance and subjective state (19–23), or positive ef-

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fects on subjective state and no effects on performance (24).

Several laboratory studies have evaluated napping in preparation for extended sleep deprivation or napping during extended sleep deprivation (25–40). Given the degree of behavioral and environmental control available in the laboratory, these studies are consistent in demonstrating that napping before or during sleep deprivation can delay the dramatic decline in performance and subjective alertness. If sufficient sleep can be obtained in the nap, alertness can be maintained near normal daytime levels during the first night of sleep loss (26).

From the laboratory studies, it might be concluded that napping prior to a night shift would have a beneficial effect on alertness. Studies directly assessing napping effects on shift-worker alertness are rare, however, and such studies are needed to verify the conclusions of laboratory studies. They are needed because the degree of control that is possible in the laboratory is not possible in the field. Shift workers are less likely to nap in a controlled environment (such as a laboratory), they are less likely to nap after an optimal 8-hour period of sleep taken the night before extended wakefulness, and they might not get enough sleep for the nap to have the desired effect. Furthermore, unlike laboratory subjects selected to be good sleepers in an habitual night–day, sleep–wake orientation, shift workers may be in a state of circadian dysynchrony and chronic sleep loss caused by frequent alternation between daytime and nighttime schedules (41,42).

Only a few studies have been conducted to assess napping effects on subsequent waking function in shift workers. Ishibashi et al. (10) reported that a group of permanent night workers and another group of rotating shift workers, who regularly split their sleep period, had less fatigue complaints than those who slept in one continuous period. Härmä et al. (18) reported daytime improvements in performance and subjective alertness in workers who napped during the daytime following morning shift. Workers who napped prior to night shift reported higher levels of alertness during night shift than nonnappers, but no differences in performance were observed. In studies of napping during night shift, Sakai et al. (13) reported lower blood pressure, better memory performance and less fatigue complaints in nappers as compared to nonnappers. Torsvall et al. (6) reported higher night-shift sleepiness and lower post-shift sleepiness in night-shift nappers compared to nonnappers.

In summary, the few studies comparing waking effects in groups of napping and nonnapping shift workers have suggested that daytime napping either improved performance and subjective state or maintained it at levels observed in nonnappers. Daytime napping decreased the magnitude or delayed the phase of the expected decline in alertness during night shift, but did not reverse it.

The present study further explores the conditions surrounding self-selected napping in shift workers and the possible association of napping with waking function. Unlike previous shift-work studies comparing separate groups of nappers and nonnappers on select shifts, the present study examined several nap and no-nap days within groups of workers in an attempt to characterize the circumstances under which a shift worker elects to take a nap and the relationship of the nap to various measures of waking function. Workers on 8- and 12-hour rotating shift schedules at two unrelated worksites were examined, providing a variety of conditions under which napping could occur. Based on previous research, it was expected that a compensatory view of napping would be supported, both by measures of sleep habits and by measures of waking alertness.

METHODS

Worksites and work schedules

The first worksite study occurred at a nuclear power plant. Control panel and computer monitoring were the main activities required of the study participants. Cognitive/problem-solving functions and maintenance of attention were the primary task factors associated with these activities. Physical demands were light. Subjects at this site originally worked on an 8-hour, rotating three-shift schedule, having 5–7 consecutive workdays. They subsequently switched to a 12-hour, rotating two-shift schedule having 3–4 consecutive workdays. Shift times for the 8-hour schedule were 0730 to 1600 hours (day shift), 1530 to 2400 hours (evening shift), and 2330 to 0800 hours (night shift). Shift times for the 12-hour schedule were 0630 to 1900 hours (day shift) and 1830 to 0700 hours (night shift).

The second worksite study took place at a natural gas utility. Workers at the central monitoring-allocation station (gas control) and at two storage-transmission stations (station 1 and station 2) participated. Gas control workers monitored control panels and computer terminals to make decisions about gas supply and allocation. Physical demands were light. Workers at stations 1 and 2 operated, repaired and maintained equipment such as gas engines, turbines, compressors and pumps. Physical demands varied from moderately light to very heavy. Some of the workers at the gas utility worked on an 8-hour, rotating three-shift schedule, having 5–7 consecutive workdays. Other subjects worked a 12-hour, rotating two-shift schedule, having

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2–3 consecutive workdays. Gas control workers were tested on both 8- and 12-hour shifts. Workers at station 1 were tested only on 8-hour shifts, and workers at station 2 were tested only on 12-hour shifts. Shift times for gas control and station 1 workers on the 8-hour schedule were 0700 to 1500 hours (day), 1500 to 2300 hours (evening) and 2300 and 0700 hours (night). Shift times for gas control workers on the 12-hour schedule were 0930 to 2130 hours (day) and 2130 to 0930 hours (night). Shift times for station 2 on the 12-hour schedule were 0800 to 2000 hours (day) and 2000 to 0800 hours (night).

Daily questionnaire

Information about napping behavior at each worksite was obtained from a questionnaire containing items about sleep and other personal factors potentially affected by shift work [see (43–45) for details]. For several weeks, this questionnaire was provided to workers selected by management. It was presented at the beginning of each workshift and workers completed the questionnaire voluntarily and anonymously (using code names). Completed questionnaires were not available from each subject on every workshift. Job demands and the voluntary nature of the study precluded obtaining complete information from every subject.

At both worksites, the workers were queried on their times of retiring and arising (including nap times), sleep latency, number of awakenings and depth and quality of their main sleep period for the 24-hour interval immediately preceding the workshift. They also noted personal schedule adjustments attributable to shift work, including adjustments of mealtimes, exercise time and absenteeism. Workers at the nuclear plant also gave their subjective evaluation of psychological stress for the previous day and their subjective evaluation of gastrointestinal state at that moment. Workers at the gas utility also reported use of sleep aids (including alcohol and prescription and nonprescription medication). Differences in some of the questions used at each worksite were a result of differences in the extent of questioning permitted by management at the particular worksite.

Participation. Napping was defined as any extra period of sleep greater than 15 minutes, occurring more than 60 minutes from the main (i.e. longest) period of sleep. Based on these criteria, only one nap was observed at the nuclear plant while the subjects worked day shift (night sleep), and only two naps were observed at the gas utility while the subjects worked day shift. Therefore, for the present study, data from day shifts were excluded from further analysis. Exclusion of day-shift data left 93 subjects (from a total of 126) from the nuclear plant with sufficient evening- and night-shift data (i.e. at least five daily questionnaires). More than 90% of these subjects were male, ranging in age from 26 to 41 years. A total of 1,724 observations were obtained from these subjects. Number of questionnaires per subject ranged from 5 to 36 (mean = 20, SD = 8). Eleven of the 93 subjects (12%) at the nuclear plant never took naps.

Nineteen subjects (out of a total of 58) from the gas utility had sufficient evening- and night-shift data. All of these subjects were male, ranging in age from 25 to 59 years. A total of 172 observations were obtained from these subjects. Number of questionnaires per subject ranged from 5 to 17 (mean = 10, SD = 4). Three of the 19 subjects (16%) at the gas utility never took naps.

Data analyses. Differences in questionnaire responses between nap conditions, shifts, workdays and their interactions were tested for statistical significance via analyses of variance (ANOVAs). Except for the ANOVA on nap frequency, subjects who never took naps were excluded from these analyses. To maximize statistical power, data from both worksites were combined for these analyses. Factors for the main effect of worksite and the interaction of worksite with all other effects were included in the ANOVA models to test for effects that were peculiar to a given worksite.

Differences in numbers of subjects at each worksite, uneven response rates among subjects, differences in the frequency of nap days and no-nap days, and the fact that some subjects experienced only 8-hour or only 12-hour shifts resulted in unequal cell frequencies in the ANOVAs. Because of unequal cell frequencies, least-squares regression solutions to the ANOVAs (46) were computed using the SAS general linear models procedure (47). Consequently, the F-ratios from these ANOVAs are not exact, and the degrees of freedom do not conform to a balanced design. To compensate for potential bias in the F-ratios, conservative degrees of freedom (i.e. 1 and $n - 1$), were adopted for tests of statistical significance in all analyses. An alpha level of $p < 0.05$, using conservative degrees of freedom, was considered statistically significant.

Performance and alertness test battery

Worksite tests of standardized performance and self-reported sleepiness were conducted with a computerized test battery developed at the National Institute for Occupational Safety and Health. The battery includes tests of cognitive, perceptual-motor and motor skills and scales for measuring subjective sleepiness or fatigue. The tasks are brief to minimize interference with the worker's regular job. Details of the components of the battery and the testing procedures have been reported previously (48,49).

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At both worksites, workers were assessed during the shift with a 3-minute test of mental arithmetic [a digit addition task adapted from Williams and Lubin (50)], a 4-minute dual task consisting of grammatical reasoning combined with auditory reaction time, four minutes (60 trials) of simple auditory reaction time [adapted from Lisper and Kjellberg (51)] and a 2-minute hand steadiness task. The reasoning component of the dual task was based on Baddeley's test (52), with the exception that response time was measured for each conditional statement rather than for the entire test. Self-reported sleepiness was measured with the Stanford Sleepiness Scale (53).

Participation. At each worksite, subjects were selected from the pool of respondents to the daily questionnaire. They were selected on the basis of their having sufficient evening- and night-shift data on both the questionnaires and the performance/alertness test battery for an analysis of differences between nap days and no-nap days (i.e. at least five questionnaires completed at the beginning of shifts having test-battery data). Nine subjects (eight male) were selected from the nuclear plant, yielding a total of 228 observations. Number of observations per subject at the nuclear plant ranged from 11 to 35 (mean = 25, SD = 8). Nine subjects (all male) also were selected from the gas utility, yielding a total of 98 observations. Number of observations per subject at the gas utility ranged from 5 to 16 (mean = 11, SD = 4).

Procedure. Portable computers were distributed in quiet, secluded areas at each worksite. The computers controlled the instructions for, and presentation of, all test-battery performance tasks and self-report scales. A brief introduction to the purpose of the study, the computers and the test battery was the only experimenter intervention before testing began. Except for a brief training session, the experimenters were not present during data collection. To initiate the test, the subject sat at the computer console and typed a simple command. Testing times occurred at random, resulting in a relatively even distribution of test times across the workshift and across the workweek. Random test timing occurred despite the original plan to schedule testing at the beginning, middle and end of selected shifts. Job demands and the voluntary nature of the study precluded adherence to the original test schedule.

Data analyses. Before analyses, several dependent variables in the test battery were transformed to approximate the normal distribution [see (46), pages 72–73]. Grammatical reasoning response time, dual reaction time and simple reaction time were transformed to their inverses. Proportion scores, such as grammatical reasoning errors, dual and simple reaction time misses and hand steadiness time off-target, were transformed to the arcsine of their square roots.

Analyses of variance on test battery scores were similar to ANOVAs of the questionnaire data, with the addition of a two-level factor for time-on-shift (i.e. early vs. late). This factor was obtained by dividing test sessions into those occurring during the first and second halves of the workshift. Consequently, each ANOVA tested for the effects of worksite, naps, shifts, workdays, time-on-shift and their interactions, using least-squares regression solutions to the ANOVAs (46,47), conservative degrees of freedom and an alpha level of $p < 0.05$.

RESULTS

Daily questionnaire

Nap frequency. Table 1 shows the average percentage of naps per subject for each shift (including subjects who did not nap). Because the majority of the naps occurred before the first day of the workweek, Table 1 is divided into naps taken before the first workday and naps taken before all other workdays. It is apparent in Table 1 that most napping occurred prior to night shift, especially the 8-hour night shift, and prior to the first shift of the week. In support of these results, the ANOVA indicated significant main effects for shift (df = 1,98; $F = 22.63$) and day (df = 1,98; $F = 6.78$). No significant main effect of worksite or interaction of other effects with worksite was observed.

Sleep quantity. Table 2 shows total sleep times on each shift for the main sleep period on no-nap days, and for the main sleep period and the nap period on nap days. As shown in Table 2, the main sleep period was shorter on nap days compared to no-nap days. The ANOVA indicated that this difference was significant (df = 1,96; $F = 16.10$). With the addition of the nap, total sleep time was greater on nap days compared to no-nap days. The ANOVA indicated that this difference also was significant (df = 1,96; $F = 9.94$). Nap length was not significantly different with respect to shift (df = 1,96; $F < 1$). No significant main effect of worksite or interaction of other effects with worksite was observed in the analyses of sleep quantity with respect to shift.

Figure 1 shows total sleep times for the main sleep period on no-nap days and for the main sleep period and the nap period on nap days. Figure 1 is divided into sleep taken before the first workday and average sleep taken between workdays. The data were divided in this manner because the high frequency of napping prior to the first workday, as compared to between workdays (see Table 1), suggested that sleep behavior before the first workday was qualitatively different than sleep behavior between workdays. Inspection of Fig. 1 supports this suggestion. It is apparent that total sleep

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TABLE 1. *Mean percentage of naps for each shift, separated as naps taken before the first workday and naps taken before all other workdays. The percentages of naps first were caculated individually for each subject and then averaged to obtain a mean and standard deviation (SD) for each cell in the table. Values in the table include 0% scores for subjects who did not nap*

	Shift			
	8-hour evening	8-hour night	12-hour night	Average
First day	7 (26)	54 (50)	47 (40)	37 (45)
Other days	10 (23)	28 (30)	9 (15)	15 (25)
Average	9 (24)	40 (42)	28 (36)	25 (37)

Values are expressed as mean (SD).

TABLE 2. *Total sleep times on each shift for the main sleep period on no-nap days and for the main sleep period and the nap period on nap days. Standard deviations are in parentheses*

Shift	Main sleep	Nap	Total sleep	Shift mean
8-hour evening				
No nap	7.32 (1.42)	–	7.32 (1.42)	7.34 (1.44)
Nap	6.02 (1.68)	1.62 (1.75)	7.63 (1.68)	
8-hour night				
No nap	6.52 (1.87)	–	6.53 (1.87)	6.83 (1.99)
Nap	5.38 (2.23)	2.11 (1.25)	7.48 (2.09)	
12-hour night				
No nap	6.79 (1.72)	–	6.79 (1.71)	7.11 (2.00)
Nap	6.23 (2.42)	2.20 (1.31)	8.44 (2.47)	

time before the first workday was greater than total sleep time during the workweek. The ANOVA of differences in sleep quantity with respect to days was significant for the main sleep period (df = 1,96; F = 21.74) for total sleep overall (df = 1,96; F = 25.56). It also is apparent in Fig. 1 that, on the first workday, the main sleep period on nap days was similar or longer in length than the main sleep period on no-nap days. During the workweek, however, the main sleep period on nap days was considerably shorter than the main sleep period on no-nap days. This result suggests that naps taken before the first workday often supplemented what appears to be an adequate quantity of main sleep, whereas naps taken during the workweek often compensated for a shorter period of main sleep. Statistical analysis supports this suggestion and shows a significant interaction of workday with nap condition (df = 1,92; F = 7.96).

Sleep timing. Figure 2 depicts median retiring and arising times for sleep on no-nap days and nap days, prior to the first workday and during the workweek, for each shift type. Error bars in the figure represent the 25th–75th percentile range of retiring and arising times. Gray bars in the figure outline a substantial portion of retiring–arising times observed during daylight hours for the first day prior to a night shift (21% on 8-hour shift and 29% on 12-hour shift).

It can be seen in Fig. 2 that overall timing of sleep prior to the first day of the workweek was more variable than the timing of sleep during the workweek. Naps consistently occurred in the afternoon hours following a longer main period of sleep and varied with the timing of the workshift, occurring later if the workshift started later.

Sleep quality and depth. At both worksites, the subjects rated the quality (poor to good) and the depth (light to deep) of the main sleep period on a 9-point scale. These ratings are shown in Fig. 3 for sleep prior to the first workday and for sleep during the workweek. It can be seen in the figure that quality and depth of sleep generally were higher on no-nap days compared to nap days, which was supported by a significant effect for nap condition, both for quality of sleep (df = 1,95; F = 11.40) and depth of sleep (df = 1,95; F = 7.27). Figure 3 also shows that overall depth and quality of sleep were higher prior to the first workday compared to the rest of the week. In support of this observation, the ANOVA revealed a significant effect for days, both for quality of sleep (df = 1,91; F = 14.24) and depth of sleep (df = 1,91; F = 7.62).

No differences in quality or depth of sleep were observed with respect to shift type, worksite or their in-

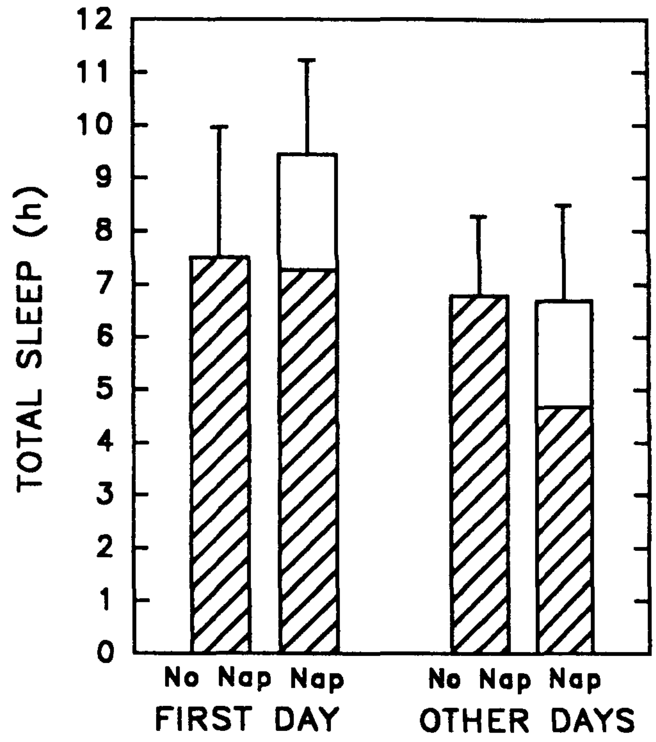

FIG. 1. Total sleep times for the main sleep period on no-nap days and for the main sleep period and the nap period on nap days, for sleep taken before the first workday and average sleep taken between workdays. Open bars in the nap conditions depict nap sleep. Error bars represent the standard deviations for total sleep time.

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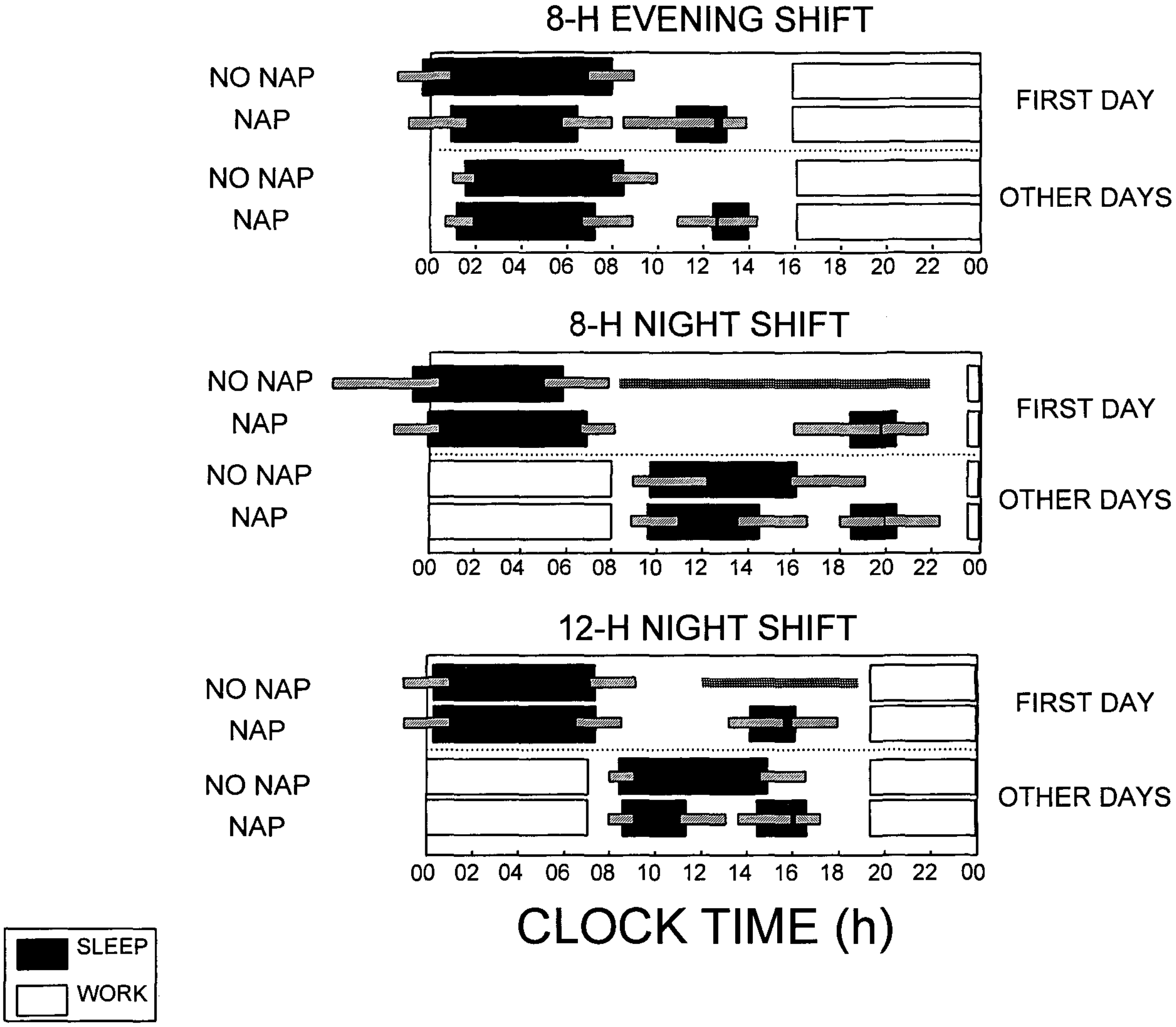

FIG. 2. Median retiring and arising times on no-nap days and nap days, both prior to the first workday and during the workweek for each shift type. Filled bars depict sleep and open bars depict work time. Error bars in the figure represent the 25th–75th percentile range of retiring and arising times.

teractions. No differences were observed in other subjective reports of sleep quality, such as estimated sleep latency, number of awakenings, total time awake during the sleep period or use of alcohol or sleeping pills.

Associated outcomes. At the nuclear plant, subjects rated their present gastrointestinal state (nauseated–fine) and their stress level on the previous day (highly stressed–relaxed) on 9-point scales. Gastrointestinal state was rated as significantly better on no-nap days (mean = 7.04) compared to nap days (mean = 6.73; df = 1,81; $F = 5.46$) and significantly better on the first workday (mean = 7.25) compared to the rest of the week (mean = 6.92; df = 1,81; $F = 8.16$). No differences with respect to nap condition were observed for the stress measure. Less stress, however, was reported prior to the first workday compared to the rest of the week (mean = 7.01 vs. 5.58; df = 1,81; $F = 47.83$).

At both worksites, subjects also noted several personal schedule adjustments. No sleep-related differences in these measures were observed.

Performance and alertness test battery

Workers reported significantly more sleepiness on nap days (mean = 2.75) compared to no-nap days (mean = 2.06; df = 1,14; $F = 7.31$) and committed significantly more addition errors on nap days (mean = 5.54%) compared to no-nap days (mean = 3.78%; df = 1,14; $F = 6.20$). Hand steadiness scores as a function of nap condition and time-on-shift are shown in Table 3. Performance on the hand steadiness task was worse during the second half of the shift on nap days compared to no-nap days. This result is supported by a significant interaction of naps with time-on-shift (df = 1,6; $F =$

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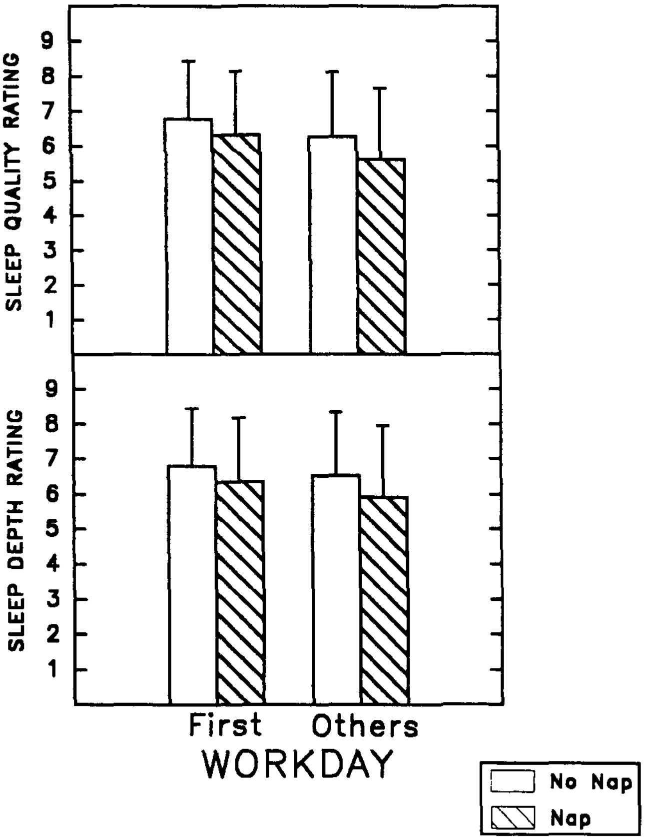

FIG. 3. Depth and quality of sleep prior to the first workday and during the workweek. Error bars represent standard deviations.

6.93). Post hoc tests among means (Newman-Keuls procedure) indicated a significant difference between the first and the second half of the shift only on nap days. No significant differences with respect to napping were observed in the dual task or the simple reaction time task. No interactions with shift type or worksite were observed in any of the test battery measures.

DISCUSSION

Sleep behavior

The results of the present study are consistent with previous studies (2–4) demonstrating that napping is common among shift workers and occurs mainly in association with night shift. Average nap lengths in the range of 0.7–2.3 hours and the timing of naps within the afternoon–evening hours also are similar to previous studies of shift workers (2–4) and of the general population (54). Unlike previous studies, however, the analysis of napping from several different workdays in the present study has provided a more detailed characterization of work schedule influences than has been reported to date.

TABLE 3. *Hand steadiness (% time off-target) as a function of time-on-shift for no-nap and nap days. Standard deviations are in parentheses*

	Shift time	
	First half	Second half
No nap	7.65 (10.92)	7.45 (9.92)
Nap	6.08 (5.70)	12.60 (13.81)

The most important work schedule influence on sleep behavior in the present study was the distinction between the first workday and the rest of the workweek. Overall total sleep time and total sleep for the main sleep period were longer on the first workday compared to the rest of the week. In addition, rated sleep depth and quality tended to be higher on the first workday and, at the nuclear plant, gastrointestinal state also was rated as better on the first workday compared to the rest of the week.

With respect to napping, the first workday was particularly influential. More napping occurred on the first workday than on all other workdays combined, and analyses of both sleep quantity and sleep timing suggested that napping served different functions on the first compared to the other workdays. Examination of sleep quantity (Fig. 1) suggested that naps often supplemented the main period of sleep on the first workday, but compensated for reduced sleep during the workweek. Examination of sleep timing (Fig. 2) prior to the first workday suggested an occasional but relatively frequent tendency to delay the main period of sleep until daytime on no-nap days, prior to both 8- and 12-hour night shifts. This tendency resulted in a bimodal distribution of sleep times on those days.

Analyses of subjective ratings of sleep indicated that the workers considered their sleep to be better on no-nap days compared to nap days. These results are somewhat consistent with those of Tepas and colleagues (11,17,18), who reported more sleep complaints in night workers who napped compared to those who did not nap. In the present study, however, poor sleep did not appear to be a stable trait associated with nappers. A supplementary analysis of data from the nuclear plant, comparing the 82 nappers with 11 workers who never napped, indicated no significant differences between the groups in sleep quantity, quality or depth on no-nap days. Similar analyses of sleep variables on nap days in the napping group, compared to the sleep of the nonnapping group, mirrored the analyses of no-nap and nap days within the napping group. Specifically, overall total sleep time did not differ between groups, total sleep time in the main sleep period was significantly shorter in the napping group (df = 1,89; F = 17.94), and sleep quality (df = 1,89; F = 3.96) and sleep depth (df = 1,89; F = 9.44) were rated lower in the napping group. These analyses indicate

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that lower quality sleep occurred mostly on nap days in the napping group—that is, it was not characteristic of their sleep in general.

In summary, whether to nap and when to nap depended on the workday, the type of shift and the length, timing and quality of the main sleep period. With some qualifications, the analyses of sleep behavior are consistent with a compensatory view of napping. During the workweek, napping was compensatory as it brought total sleep time to the level of nonnap days. Napping also was compensatory in that it tended to occur following lower quality main sleep. Prior to the first workday, however, napping served other potentially noncompensatory roles in supplement to a normal amount of main sleep. Further data are needed, however, to determine whether these naps were taken for prophylactic purposes, "appetitive-enjoyment" purposes (55) or for the purpose of phase-delaying sleep into daytime.

Waking alertness

Greater sleepiness and diminished performance on some tasks were observed during the workshift on nap days compared to no-nap days. These results do not support a compensatory view of napping, and they are contrary to laboratory studies of prophylactic napping (25–39), which demonstrated improvements in performance/alertness during 1 or 2 nights of continuous wakefulness. The results also are contrary to the few studies of shift-worker daytime napping (10,18), where improvements in subjective alertness were observed during night shift.

In the present study, some of the factors possibly influencing diminished waking function on nap days are the quality and timing of the main sleep and circadian rhythm adjustment/adaptation. With regard to sleep quality, workers in the present study often reported inferior sleep on nap days. Subjects in controlled laboratory studies (25–39), by contrast, were more likely to get a good night of sleep before their nap day. Similarly, nappers in the shift-work study by Härmä et al. (18) reported significantly less sleep disturbance than nonnappers, which may have contributed to the smaller decrease in nappers' alertness observed during night shift.

Other factors producing diminished alertness on nap days may have resulted from the interaction of sleep timing with adjustment of the circadian performance or alertness rhythms. It is possible, for example, that the main sleep period acted as an "anchor" for the circadian rhythms (56,57), and nap sleep was insufficient to establish a new anchor point to facilitate the phase-delay of performance/alertness rhythms into the nighttime hours. Alternatively, napping and reduced alertness could have been passive reflections of some other factor producing poor circadian adaptation/adjustment. Lower gastrointestinal ratings on nap days compared to no-nap days, for example, would be consistent with poor overall circadian adjustment.

Definitive support for these hypotheses cannot be obtained from the post hoc analyses of self-selected sleep patterns in the present study. Such support could be obtained, however, from direct manipulation of continuous- and split-sleep routines under work schedules commonly used by shift workers. The ultimate goal from those endeavors would be the design of sleep strategies that would improve alertness and promote adjustment of circadian rhythms. The present and previous studies of napping indicate that factors to be considered in designing sleep strategies would include (a) the quantity, quality and circadian timing of the main period of sleep, (b) the quantity, quality and circadian timing of the nap, (c) the positioning of the nap within the work schedule and (d) the degree of circadian adjustment of the worker.

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