Rotating Shiftwork Schedules: Can We Enhance Physician Adaptation to Night Shifts?

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ABSTRACT

Objectives: To evaluate the effectiveness of a broad, literature-based night shiftwork intervention for enhancement of emergency physicians' (EPs') adaptation to night rotations.

Methods: A prospective, double-blind, active placebo-controlled study was conducted on 6 attending physicians in a university hospital ED. Three data sets were collected under the following conditions: baseline, after active placebo intervention, and after experimental intervention. In each condition, data were collected when the physicians worked both night and day shifts. Measurements included ambulatory polysomnographic recordings of the main sleep periods, objective performance tests administered several times during the subjects' shifts, and daily subjective ratings of the subjects' sleep, moods, and intervention use.

Results: The subjects slept an average of 5 hr 42 min across all conditions. After night shifts, the subjects slept significantly less than they did after day shifts (5 hr 13 min vs 6 hr 20 min; $p < 0.05$). The physicians' vigilance reaction times and times for intubation of a mannequin were significantly slower during night shifts than they were during day shifts ($p = 0.007$ and $p < 0.04$, respectively), but performances on ECG analysis did not significantly differ between night and day shifts. Mood ratings were significantly more negative during night shifts than they were during day shifts (more sluggish $p < 0.04$, less motivated $p < 0.03$, and less clear thinking $p < 0.04$). The strategies in the experimental intervention were used 85% of the time according to logbook entries. The experimental and active placebo interventions did not significantly improve the physician's performance, or mood on the night shift, although the subjects slept more after both interventions.

Conclusions: Although the experimental intervention was successfully implemented, it failed to significantly improve attending physicians' sleep, performance, or mood on night shifts. A decrease in speed of intubation, vigilance reaction times, and subjective alertness was evident each time the physicians rotated through the night shift. These findings plus the limited sleep across all conditions and shifts suggest that circadian-mediated disruptions of waking neurobehavioral functions and sleep deprivation are problems in EPs.

Key words: emergency medicine; sleep; shiftwork; circadian rhythm; physician; clinical performance; sleep deprivation.

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Since 1882, continuous and low-cost electrical lighting has provided support for 24-hour work operations. Rotating shifts, permanent night duty, and long continuous shifts are a few of the general designs used today to allow employees to share the costs and benefits of working around-the-clock. Society has come to depend on these continuous operations in many fields such as public safety, manufacturing, transportation, and health care.

Approximately 25% of America's workforce has a rotating work-shift schedule,[1] with 10% engaged in night work. Sleepiness and decreased performance can increase vulnerability for the occurrence of unintentional incidents. Decreased performance related to sleep loss and circadian disruption has been implicated in motor vehicle crashes and fatalities,[2] and in some recent disasters (Three Mile Island; Challenger explosion).[3]

Repeatedly changing hours of work disrupts an individual's sleep and circadian rhythms. This cumulative sleep loss and circadian rhythm disruption lead to decreased alertness, poor performance, and negative moods.[4,5] Vidacek et al.[6] found that workers tend to lose 1 to 4 hours of sleep each night for approximately 3 days after they rotate shifts. Losing even 1 hour of sleep each

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TABLE 1 Strategies to Promote Sleep and to Promote Alertness at Work

To promote sleep:
- Slept in a dark room (blindfold, curtains, etc.)
- Slept in a quiet room (phone off, closed door, earplugs, etc.)
- Comfortable sleep surface (no extremely hard or soft surfaces)
- Comfortable temperature where sleeping
- Refrained from caffeine at least 4 hr before sleep
- Regular noise to mask disturbances while sleeping (fan, etc.)
- If hungry at bedtime, ate a light snack
- Refrained from eating or drinking heavily just before sleep
- Maintained usual 24-hr organization of activities on new clock times
- Practiced a regular presleep ritual
- Used the bedroom only for sleep; avoided work, worrying, and workouts
- If couldn't fall sleep <30 min, got up to do something conducive to sleeping (read, watch TV); avoided tossing and turning
- Slept your "ideal" amount (the amount you need to be alert, no more)
- Awakened at a regular time
- Relieved of household responsibilities while sleeping (parenting, etc.)
- Moderate exercise during afternoon or evening
- After a nightshift, slept as long as you could
- Before AM sleep, avoided sunlight exposure prior to sleeping (<30 min)
- After AM sleep, had exposure to bright light (sunlight). For how long? _____
- Before a nightshift, took >1-hr nap that ended at least 30 min prior to shift
- Medical sleeping aids, what did you take? _____

To promote alertness at work:
- Physical activity (walking, chewing gum, writing, etc.)
- Exposure to cooler temperatures (outside, cold room, etc.)
- Brightly lit work environment
- Bright light exposure during your shift
- Heavy workload
- High motivation
- Active interactions (with peers, students, etc.)
- Strategic caffeine consumption
- Napping
- Variation of activities, especially when bored

night for a number of days can increase waking levels of sleepiness.[7] Approximately 75% of night workers experience sleepiness on their shifts and 20% report actually falling asleep while on duty.[8] Cumulative sleep loss, the number of continuous waking hours, and the time of day all can affect the extent of sleepiness and decreased performance. Chronic disruptions of circadian rhythms and sleep may be associated with a range of risks, including sleep–wake disorders, gastrointestinal problems, and cardiovascular disease.[9]

Twenty-four-hour operations can adapt their schedules to minimize workers' sleep and circadian disruptions. It is thought that because the human biological clock has a period slightly longer than 24 hours, if no environmental cues are provided,[10] it is easier to adjust to a clockwise shift rotation (i.e., day to evening to night) than the reverse.[11,12] Bright light exposure, napping, and good sleep hygiene or habits (e.g., the avoidance of environmental stimuli such as noise, alcohol, and caffeine) are other strategies suggested in the medical literature to improve circadian adaptation, sleep, and performance while rotating shift schedules.[13–15]

A recently completed pilot study of 6 attending physicians in the Stanford University Hospital ED found that physicians suffered from decreased sleep and mood ratings when working night shifts and sleeping during the day, as opposed to day shifts with sleep at night. The physicians also showed decrements in performance on a battery of tests after working 3 consecutive nights when compared with working 3 consecutive day shifts.[16]

The objective of the current study was to test the effectiveness of a broad, literature-based shiftwork intervention in emergency physicians (EPs) to determine whether adaptation to night rotations could be enhanced. An important goal of this study was to determine the feasibility of implementing such a program by working academic EPs.

METHODS

Study Design: A prospective, double-blind, active placebo-controlled study was conducted on 6 attending physicians in a university hospital ED. The intervention was a broad, literature-based program designed to enhance adaptation of faculty EPs to night rotations. The study measured both objective and subjective variables at baseline and following the implementation of the experimental intervention program compared with an active placebo intervention. The study was approved by the Stanford University's human subjects committee and informed consent was obtained from all subjects.

Setting and Population: The study was performed at the Stanford University Hospital ED. The ED sees 37,000 patient visits annually. Approximately 16% of visits are evaluated between 0000 and 0800. Six faculty members out of a clinical faculty of 8 participated. These faculty members had an average academic career of 8.2 years (range 5–10 years). Additional subject demographic data are provided with the study results.

Interventions: Details regarding scheduling are provided in a separate section. The experimental and placebo intervention programs are outlined below:

1. *Experimental Program:* A 3-component experimental intervention was designed based on a fatigue countermeasure program used for commercial airline pilots developed at the NASA/Ames Research Center. First, the physicians had a 2-hour education session that provided information about normal sleep physiology, circadian

rhythms, good sleep hygiene, and chronobiologic principles of scheduling. The videotape of this session was made available to the subjects' significant others. Second, a more regular work schedule was designed according to accepted chronobiologic principles. Numerous schedule design criteria were used to allow adaptation to shiftwork. These criteria included rotating shifts in a clockwise direction (i.e., working days followed by evenings, followed by nights), limiting the number of consecutive night shifts to 2, and scheduling 48 hours off duty to recover from the disruption of working a night shift. The third component of the experimental intervention provided 31 countermeasure strategies to maintain alertness and performance during work (Table 1). The physicians were instructed to use these strategies extensively and to record which ones they used. These strategies were taught during the educational session.

2. *Active Placebo:* This intervention was based on "the jet lag diet," a dietary manipulation described by Ehret and Scanlon[17] in which carbohydrate and protein intake was manipulated for the 3 days prior to an 8-hour airplane flight. In the present study, switching to night shifts was considered to have approximately the same circadian effect as an 8-hour time change and therefore the Ehret and Scanlon diet for an 8-hour time change was followed as the active placebo. The diet was considered a placebo because Moline et al.[18] studied the effects of this jet lag diet on 15 male subjects while they were in time-isolated apartments and found the diet intervention to be ineffective. The physicians were asked to adhere to the diet and were blinded to the fact that the diet was a placebo. If the physicians were randomized to this intervention first, they also received general information about normal sleep physiology and circadian rhythms. This educational session also lasted 2 hours, but did not include information about good sleep hygiene or the best time to schedule meetings. The physicians' random work schedule remained as in the baseline condition, and the physicians were not given countermeasure strategies to maintain alertness and performance during work.

Measurements: Data were obtained using the following tools:

1. *Subjective Logbooks:* The subjects were asked to complete a daily sleep/wake diary for 1 week before and after each testing period, regardless of the day's activities. Each testing period included a day shift and a night shift, which were usually 2 weeks apart. Therefore, the logbooks were completed for 3 to 4 weeks on average during each testing period. Prior to going to bed, the subjects rated their levels of alertness, napping habits, and moods for the preceding waking period. Upon awakening, the subjects completed questions about the quantity and quality of sleep obtained and their levels of alertness on the Stanford Sleepiness Scale. During the experimental intervention, the subjects also recorded each day which of the 31 suggested strategies were used to improve alertness. A subjective evaluation of their effectiveness was recorded. The individuals who keyed in the data from the subjective logs were blinded to the research design. During the active placebo intervention, the time, content, and amount of food were recorded but not evaluated because it was a placebo.

2. *Polysomnographic Recordings:* Polysomnographic data were collected during the main sleep period at home on each of 6 testing days (day sleep and night sleep in 3 conditions). All polysomnographic data were collected with Oxford Medilog 9000 (Oxford Medical Inc., Clearwater, FL) ambulatory recorders. Standard polysomnographic variables were measured using an EEG placed according to the conventional 10–20 placement system (C3, O2, A1, A2), electro-oculography (EOG) from outer canthi, and electromyography (EMG) from chin electrodes.[19] These measurements allowed physiologic differentiation of the stages of sleep, including analysis of sleep latency, total sleep time, sleep efficiency, stage 1 sleep, stage 2 sleep, slow wave sleep [nonrapid eye movement (NREM) stages 3 and 4], and REM sleep. All tapes were analyzed by an experienced technologist on a Telefactor playback system and scored visually according to accepted Rechtschaffen and Kales criteria.[19] The technician was blinded to the experimental design.

3. *Performance Tests:* Performance data were collected during the same 24-hour periods as were the polysomnographic recordings. Performance was measured by a battery of 3 tests that were administered at 4 times across the day. Performance was first measured when the subjects woke up from their primary sleep period. This condition was thought to represent the most rested state of the subjects on a particular schedule. The performance battery was also administered at the beginning, middle, and end of each shift. The performance tests were administered and analyzed by individuals who were blinded to group assignment. The following performance data were collected at each testing session:

a. VIGILANCE/SUSTAINED ATTENTION: A psychomotor vigilance task (PVT) was used to evaluate sustained attention while on shift. The PVT is a high-signal-load, simple, sustained-attention, visual reaction time (RT) test. The subjects watched an LCD display for 10 minutes and pressed a response button as fast as possible each time the LCD light illuminated. This test has been demonstrated to be a sensitive measure of the effects of circadian variation and sleep loss on sustained attention and vigilance.[5,20,21] The number of PVT lapses (RT > 500 msec) and the median RT were analyzed.

b. ECG/RHYTHM INTERPRETATION: This test involved interpretation of 2 12-lead ECGs and 1 1-lead rhythm strip. Both speed and accuracy were used to evaluate physician performance and interpretation. Recordings were

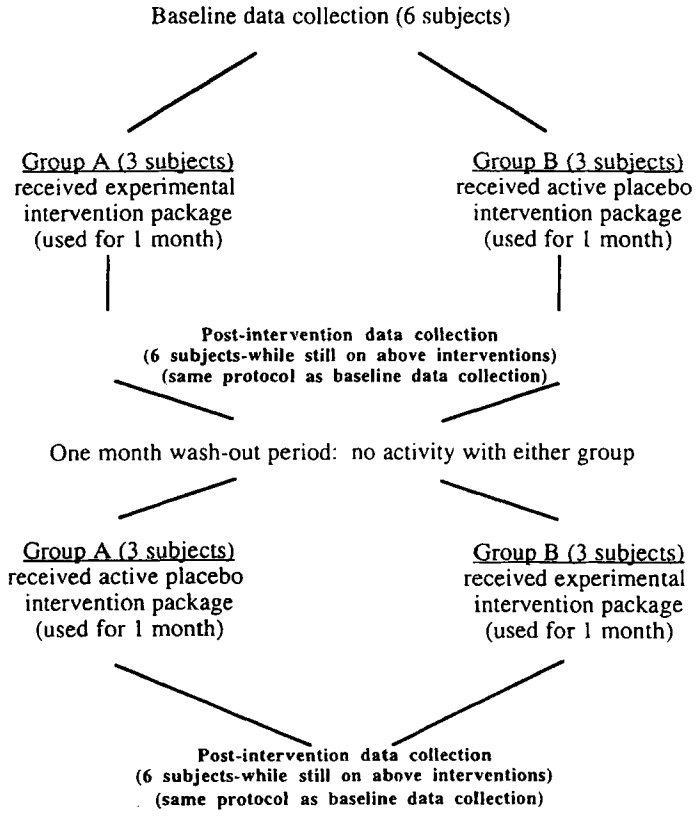

FIGURE 1. The randomized crossover design.

randomly selected from a set used for cardiology boards review. Two board-certified cardiologists independently scored each recording, which was used as a key. The cardiologists' ratings of 256 items were identical on 77% of responses. Interpretations were graded for rate, rhythm, intervals, axis, morphology, and a clinical diagnosis. Answers were marked correct if the subjects agreed with one or both of the cardiologists. Answers were marked incorrect only if both cardiologists agreed upon the interpretation and the subject's interpretation was different. The percentage of correct answers was then calculated for accuracy. Rhythm strips were graded similarly: if the subject's interpretation agreed with one or both of the cardiologists, the subject was given a score of "1." If the interpretation was different from that of the concurring cardiologists, the subject was given a score of "0."

c. INTUBATION: The motor performance of each subject was tested in a simulated intubation using a mannequin (Model #080001, Laerdal Medical Corp., Horten, Norway) and standard Advanced Cardiac Life Support protocol. Intubation performance was scored using the following 7 criteria: ensuring an intact balloon on the endotracheal tube, connecting the blade to the laryngoscope correctly, ensuring that the light on the blade was working, using the correct hand in holding the laryngoscope, visualizing the vocal cords, successfully intubating the mannequin, and not using the teeth as a fulcrum. Subjects were given credit for correct intubation only if they met all 7 criteria. This test was found to be a sensitive measure of performance during a prior investigation.[16]

Scheduling and Experimental Protocol: The 6 attending physicians in the ED at Stanford University Hospital were studied under each of 3 conditions: baseline, experimental intervention, and active placebo intervention. Figure 1 outlines the data collection schedule for all 6 subjects. All the subjects were studied under baseline conditions first and then were randomly assigned to either group A or B to do experimental intervention or active placebo intervention, respectively. The subjects were blinded to the fact that the diet was an active placebo. After data were collected and a 1-month washout period had elapsed, the subjects were crossed over. Data collection periods consisted of a 3–4-week period during which the physicians completed their daily subjective logs. Subjects' shifts at baseline rotated randomly according to the personal preferences of individual physicians and the needs of the department. Each subject had 10–16 8- or 9-hour shifts per month with 4–5 of those being night shifts. The nights were lumped in blocks of 3 and 2, although 2 of the physicians preferred their nights in 1 block of 5. No attempts were made to control the pattern of shifts for baseline and active placebo evaluations because the random nature of shifts vs strict adherence to chronobiologic scheduling was one aspect that was being tested. During each data collection period (Fig. 1), polysomnography and performance tests were done during appropriate 24-hour blocks (0800–0800 during day shifts and 0000–0000 during night shifts). In order to be able to compare sleep and performance across conditions, the data collection period for polysomnography and performance tests occurred on the second of 2 day shifts and the second of 2 night shifts. During the experimental intervention, the number of night shifts was limited to 2 to have sound chronobiologic scheduling and the subjects were instructed to sleep as long as possible after their night shifts.

Group A received a 2-hour education session discussing the 3-component experimental intervention described previously. The other 3 subjects were assigned to group B, which also received a 2-hour educational session. The first hour included the same educational information about sleep physiology and circadian rhythms. During the second hour, the control intervention involving diet manipulation was discussed. Group B were also asked to track their intervention habits on a daily questionnaire over the next month in the same fashion as were group A.

Following the 1-month intervention period, a postintervention data set was collected while the subjects were doing the interventions. The data were collected in the same manner as was done for the baseline period. After all the subjects had completed the second set of data col-

lection, they were asked to stop the intervention strategies they had been using and were given a 1-month rest period to return to their baseline habits. The subjects were then crossed over. Each group received a 1-hour session explaining their new intervention. The subjects were then asked to track their intervention use over another 1-month period, after which a third data set was collected in the same manner as the previous 2 but while the subjects were actively doing the interventions. Finally, each subject was interviewed for 1 hour after data collection was complete to learn which aspects of the intervention they considered most useful and effective.

Data Analysis: The effects of night work and the interventions were examined by determining the intrasubject differences between night and day shiftwork. The SAS statistical program (Version 6.11, SAS Institute Inc., Cary, NC) was used to analyze the data. The χ^2 test of association was used to test response frequencies for significance with respect to the strategies used for improving sleep and alertness during the intervention. For the sleep, performance, and mood variables, repeated-measures ANOVA (proc GLM in SAS) was used for possible main effects and 2-way interaction. Where appropriate, a post-hoc Tukey test was used. The Friedman test statistic was used to compare the PVT performance scores across shifts and conditions. That is, the test evaluated systematic variation in median RT and lapses over time within day and night shifts and between treatment conditions. A significance level of 0.05 was used throughout.

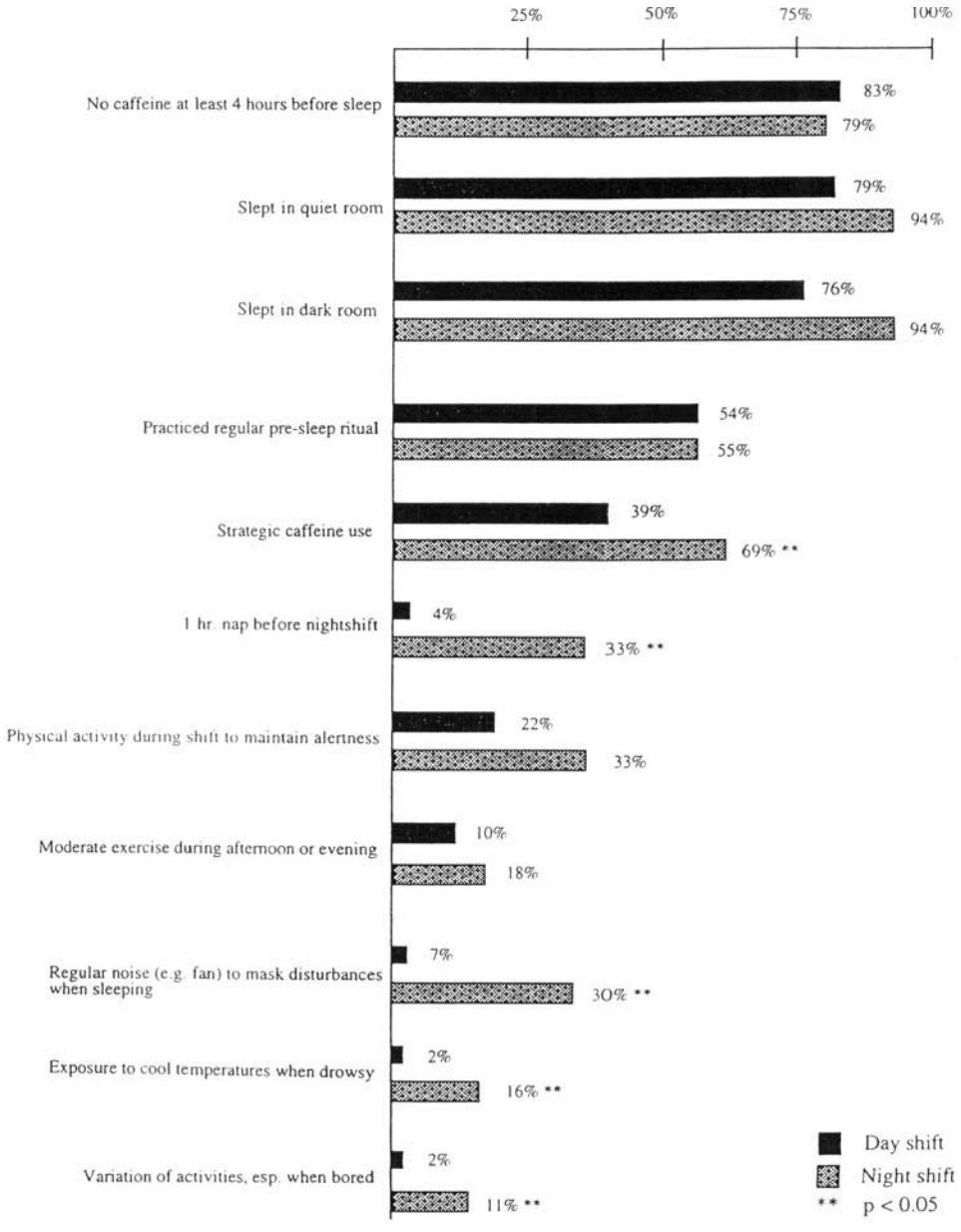

FIGURE 2. Percentage of days that the intervention strategies were used by the physicians.

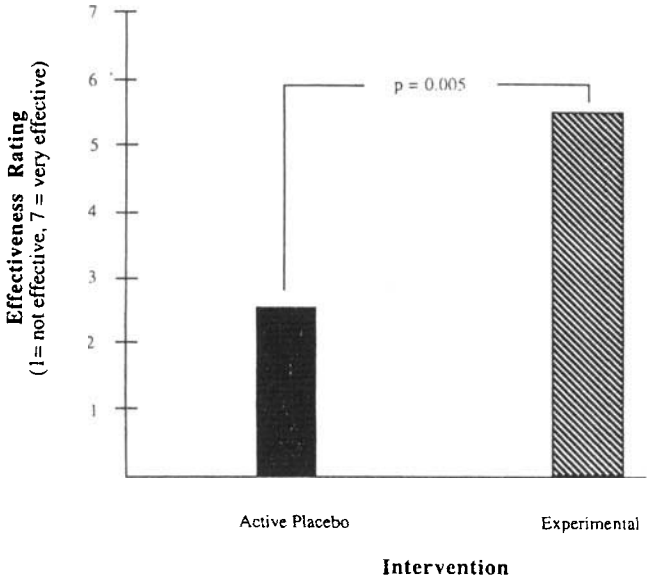

FIGURE 3. Mean ratings by the subjects at exit interviews of intervention effectiveness.

RESULTS

Demographics: Six male attending EPs (aged 34 ± 2.0 years) were studied under all 3 conditions described above. All the subjects completed emergency medicine (EM) residencies and were board-certified. Five subjects were married and 2 had children. The subjects' clinical responsibilities varied according to their academic assignments. Their monthly shift requirements ranged from 10 to 16 shifts. All shifts were 8–9 hours and were equally divided into day shifts (0800–1600 or 1200–2100), evening shifts (1600–0000), and night shifts (0000–0800).

Intervention:

Implementation: Educational sessions were completed as planned, except 1 subject in group B required a separate session due to personal schedule conflicts. He received the same information as did all other subjects. Scheduling shifts according to the chronobiologic principles also proved to be difficult despite having only 3 of the attending EPs on the experimental intervention at any time. In order to satisfy the monthly responsibilities of each subject, the afternoon shift (1200–2100), which provided double coverage during peak hours, was treated as a day shift. This shift provided a usual nocturnal sleep period, hence its classification as a day shift. Therefore, the physicians were occasionally scheduled to work a morning shift following an afternoon shift. This pattern seemed justified since it did not compromise the principle of phase delaying one's working hours because the main sleep period occurred at the same time as morning shifts. In order to collect 3 sets of data and implement 2 different interventions, data collection occurred over approximately 18 months.

Experimental Intervention Use: An important goal of this study was to organize the numerous strategies that have been suggested in the scientific literature into a coherent package that physicians could adopt into their daily routines. Figure 2 shows the 11 most frequently used strategies while the physicians worked day and night shifts (per daily logs). Percentages were calculated by dividing the number of times a strategy was used by the total number of subject responses. The subjects used more strategies while sleeping during the day (i.e., working a night shift) vs sleeping at night (i.e., working a day shift). There were proportional use differences in strategic caffeine use ($p < 0.05$), napping before night shifts ($p < 0.05$), using masking noise such as a fan during day sleep ($p < 0.05$), varying their activities when bored ($p < 0.05$), and exposing themselves to cool temperatures when feeling drowsy ($p < 0.05$). All 6 subjects used the shift scheduling principles during the experimental intervention because these were incorporated into their monthly schedules by the experimenter only during the experimental intervention phase of the experiment.

Active Placebo Intervention: After data collection was complete, all of the subjects reported (per daily logs) having used the active placebo intervention 37% of the

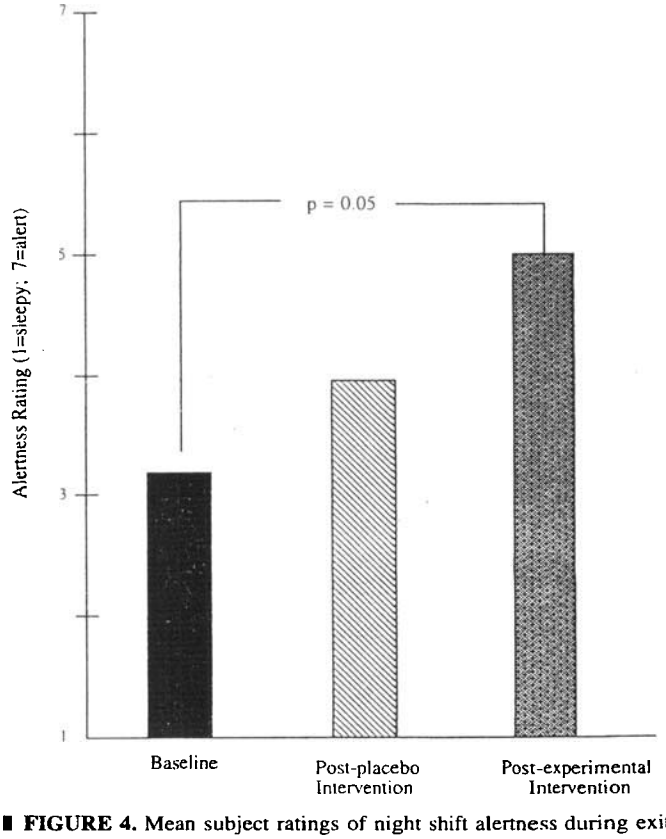

FIGURE 4. Mean subject ratings of night shift alertness during exit interviews.

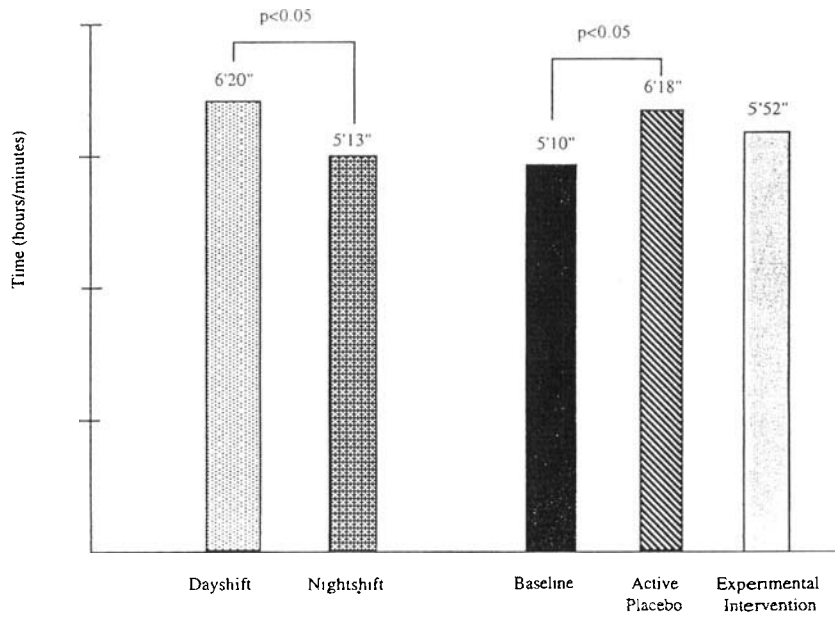

FIGURE 5. Average total sleep time of the subjects from ambulatory EEG recordings.

time, which was significantly less than the reported 85% use of the experimental intervention ($p = 0.02$).

Exit Interviews: After data collection was complete, 1-hour exit interviews showed that the physicians subjectively rated the experimental intervention significantly more effective than the active placebo intervention (Fig. 3). Subjects rated sleeping in a dark and quiet sleeping environment without family responsibilities, physical activity on duty, and a prenight shift nap as the most effective countermeasures. They also believed that their nighttime alertness was significantly better after the experimental intervention than during either the baseline or active placebo condition (Fig. 4).

Polysomnographic Data: Due to a technical problem, 25% of the baseline polysomnographic data were lost. Analysis was completed with the remaining baseline data and complete postintervention data. Figure 5 shows the average amount of the subjects' physiologic sleep under selected conditions. Throughout all 3 conditions, the subjects slept approximately 1 hour less after working night shifts (5 hr 13 min) than after day shifts (6 hr 20 min) ($p < 0.05$). The subjects also slept less during the baseline phase (5 hr 10 min) relative to either the experimental intervention (5 hr 52 min) or the active placebo control (6 hr 18 min). However, only the active placebo was significantly different from the baseline condition ($p < 0.05$). The subjects slept an average of 5 hr 42 min across all conditions.

In addition to these differences in total sleep times, there were other significant differences between the groups in sleep physiology. Total REM time increased from 63.64 min during baseline to 85.38 min during the intervention ($p < 0.03$). The following differences were evident in total REM percentage (tREMper). Day shift tREMper during baseline (27.65%) differed from night shift tREMper during baseline (18.20%) ($p < 0.003$). Day shift tREMper during baseline (27.65%) differed from day shift tREMper during active placebo (21.58%) ($p < 0.05$). Night shift tREMper during baseline (18.20%) differed from night shift tREMper during the experimental intervention (23.05%) ($p < 0.02$). Conversely, the subjects had significantly more slow-wave sleep during baseline data collection than during either the experimental intervention or the active placebo ($p < 0.05$).

Performance Tests: Performance tests could be consistently administered within the time and space constraints of the attending physicians' responsibilities.

Psychomotor Vigilance Task: Two primary variables were extracted from performance of each of the 10-minute PVT trials: median RT and total number of lapses (i.e., RTs $\geq$ 500 msec). PVT performances were comparable regardless of the intervention used (Fig. 6). That is, neither the experimental nor the active placebo intervention altered PVT performance. There was evidence of longer median RTs and more lapses during the later portion of the night shift under all 3 conditions. To obtain a better estimate of the effect of shift on performance, data were averaged across the 3 interventions. No variation was found across the day shift on either performance measure. However, median RT increased significantly across the night shift ($p = 0.007$). PVT lapses also increased across the night shift, but the effect was not statistically reliable due to 2 subjects' showing no change.

ECG/Rhythm Strip Analysis: Overall, the physicians

TABLE 2 Power and β-error for ECG/Rhythm Strip Speed and Accuracy

	Power	β-error
Across shifts (day vs night)		
ECG speed	0.05	0.95
ECG accuracy	0.05	0.95
Rhythm speed	0.07	0.93
Rhythm accuracy	0.11	0.89
Across conditions (baseline, experimental intervention, and active placebo)		
ECG speed	0.13	0.87
ECG accuracy	0.05	0.95
Rhythm speed	0.06	0.94
Rhythm accuracy	0.05	0.95

completed the ECG interpretations in 111 seconds, with an accuracy of 65%, and the rhythm strips in 62 seconds, with an accuracy of 59%. No significant differences in speed or accuracy between shifts or across the 3 conditions were found. The power and β-error for ECG/rhythm strip speed and accuracy are as shown in Table 2.

Intubation: The physicians were significantly slower at intubating while working night shifts vs day shifts ($p < 0.04$) (Fig. 7). However, we also found that the physicians were faster at intubating during the later hours of their shifts ($p < 0.05$). This may represent a practice effect. Accuracies of intubation did not significantly differ between the shifts (power = 0.06) or across the 3 conditions (power = 0.07).

Subjective Logbook: The physicians reported feeling significantly more sluggish ($p < 0.04$), less motivated ($p < 0.03$), and less clear thinking ($p < 0.04$) while working night shifts vs day shifts (Fig. 8). There was a trend to report feeling less happy ($p < 0.10$), less alert ($p < 0.07$), less effective ($p < 0.07$), and less friendly ($p < 0.10$) while

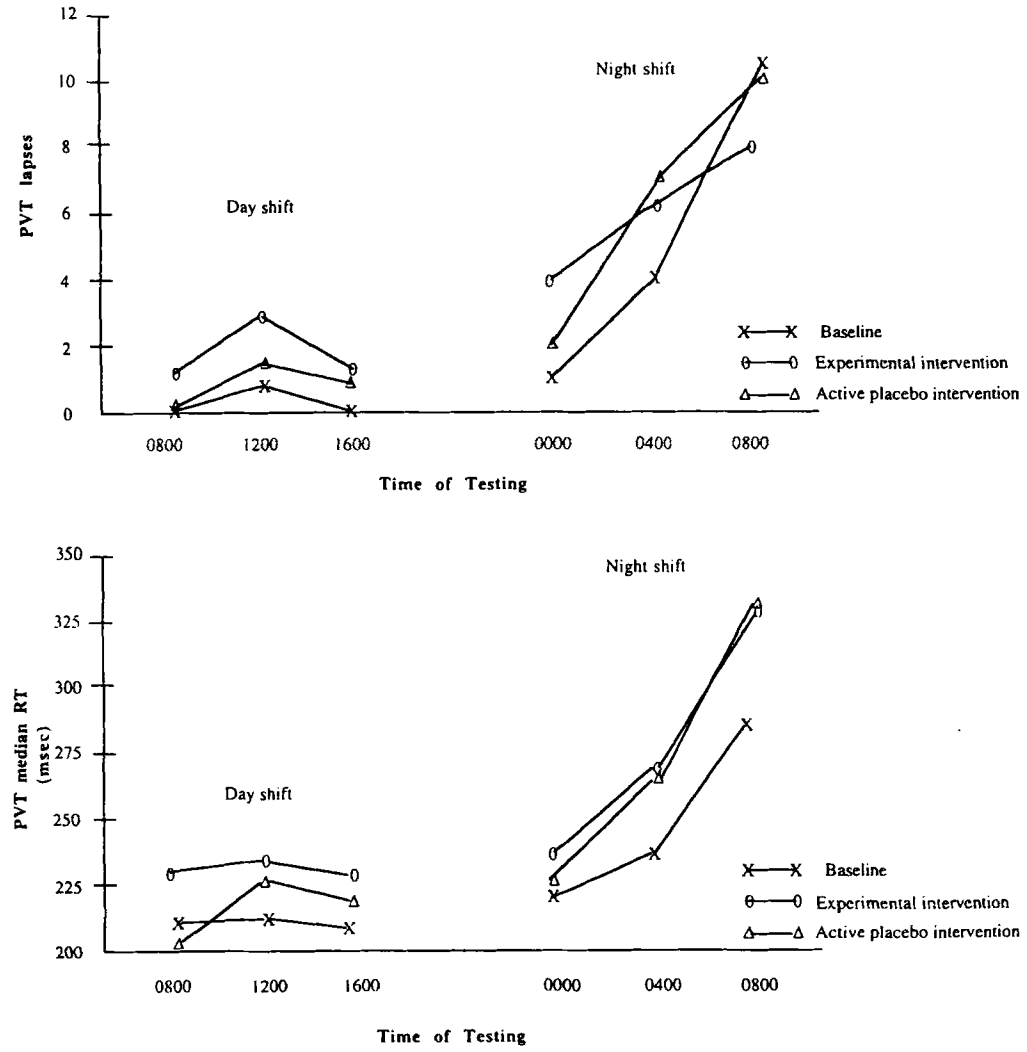

FIGURE 6. Plot of the psychomotor vigilance task (PVT) performance results by condition. RT = reaction time.

working nights vs days. Subjective data collected after both interventions did not show a significant change in physician mood ratings (power = 0.05) for all moods across conditions.

Subjective reports about sleep showed similar results. The subjects reported sleeping significantly less ($p < 0.01$), feeling less rested ($p < 0.01$), having significantly lighter sleep ($p < 0.01$), and feeling more sleepy upon awakening ($p < 0.02$) after sleeping during the day vs night. Again, there were no significant changes in the subjects' reports after either intervention.

DISCUSSION

Emergency physicians are among the 10% of the American workforce that works night shifts and experiences the detrimental consequences of disrupted circadian rhythms.[3] The focus of this study is to examine numerous strategies implemented as an intervention package to try to improve the quality and quantity of day sleep, work performance, and mood of physicians on night shifts. The strategies (chronobiologic principles guiding the schedule, education in sleep hygiene, and the host of countermeasure strategies to maintain alertness and performance while at work) were not studied separately, but as a package.

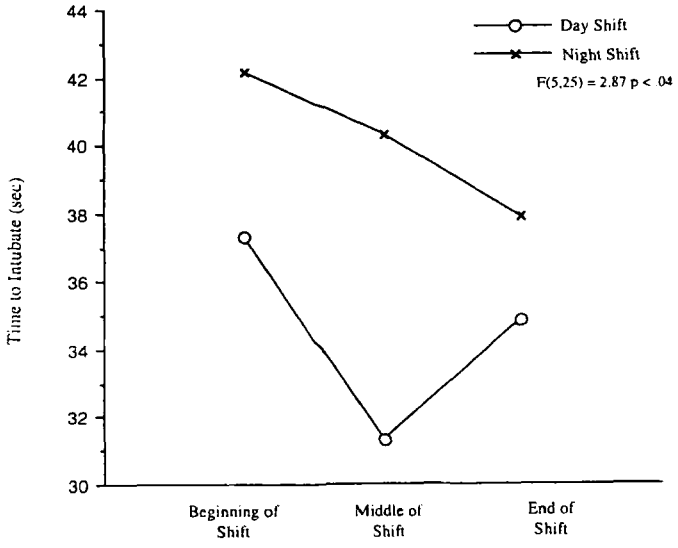

FIGURE 7. Plot of the intubation time average across all conditions. The p-value refers to the grand mean difference between day and night shifts.

There was no significant improvement in total sleep. We did find differences between day sleep and night sleep milar to those reported in our pilot study,[16] i.e., that sub-

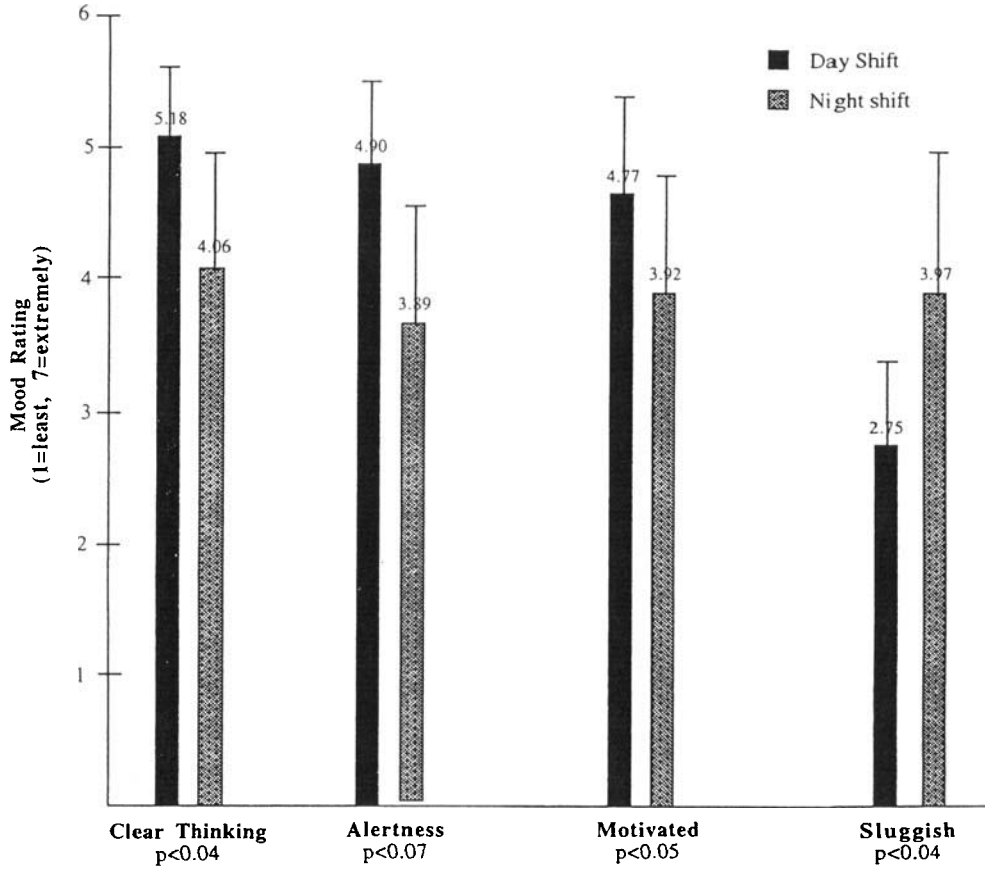

FIGURE 8. The mean subjective mood ratings during baseline data collection from daily logs.

jects slept less during the days than at night. Although the subjects slept more after both interventions, circadian effects on alertness and performance were still clearly evident with deficits in alertness, performance, and mood.

The attending physicians in this project and the original pilot study showed decrements during night shifts similar to sleep-deprived residents reported in the literature. Samkoff and Jacques[22] concluded that sleep-deprived residents were most consistently impaired when performing longer tasks that required vigilance. The attendings in the current study performed significantly worse on 10-minute psychomotor vigilance tests at night vs day shifts. The sleep-deprived residents studied by Samkoff and Jacques (like our attending physicians) also reported more negative mood states and felt subjectively more fatigued. On the other hand, the residents were able to compensate when evaluated on short tasks, which may be similar to the attendings' being able to interpret ECGs and rhythm strips. This assumes that ECG/rhythm strip interpretation is an accurate and sensitive measure of a clinically relevant function.

The attending physicians were quite interested in altering their schedules to improve adaptation to rotating shifts. Coordinating the personal schedules of multiple busy attendings with the sleep hygiene and chronobiologic principles applied in this study and fulfilling the continuous coverage of the ED proved to be difficult. Given that only 3 subjects were involved with the intervention at any time, logistic factors may limit scheduling modifications.

The present study confirmed previous findings that repeated circadian rhythm disruptions and sleep deprivation due to working night shifts result in negative changes in physicians' moods, performance of sustained tasks, and intubation speed. The implementation of a comprehensive intervention into the real-life setting of an ED proved difficult but was successfully accomplished based on the fact that the subjects reported using the intervention 85% of the time. Given that the physicians reported that the experimental intervention was effective (Fig. 3), a larger study may unmask objective evidence of improvements from these interventions. The intervention did increase total sleep time, but it did not eliminate the circadian-mediated declines in function seen in the physicians while on night shifts. Other interventions, such as appropriately timed bright light, may be needed to accomplish the latter. The established routines of the subjects, that already incorporated many of our interventions, prevented significant alterations in some subjects' daily work/rest habits or timing. More acute and rigid interventions such as a more specific work schedule that follows established circadian principles or alteration of shift length might prove more feasible and successful. As more medical school graduates choose EM as a career, the issues of circadian influences and rotating shiftwork will persist. Further attention to these issues now will strengthen the specialty's service and physician performance and alertness in clinical practice.

LIMITATIONS AND FUTURE QUESTIONS

The main limitation of the study is the small sample size. Given this small sample, there was insufficient power to demonstrate effectiveness statistically in many measures. For example, we were unable to demonstrate significant changes in physicians' sleep and performance. Given our intent to study physicians' sleep habits over an extended period and under multiple conditions, in one practice setting, our sample size was externally constrained. Although a shorter, more focused study would have provided more subjects, it would not have given us the opportunity to study the experimental intervention program and active placebo control. Further, such a short study would be more susceptible to acute variations in subjects' sleep patterns. Finally, the enormous variety of ED work schedules among different institutions and the complex logistics of data collection in a multicenter trial were factors that directed us to limit the study to a carefully controlled setting during this evaluation. However, the study trends are interesting and warrant further evaluation in a larger sample.

One must also entertain the possibility of a Hawthorne effect (i.e., by subjects' merely knowing that they are being studied, their behavior may change). The presence of a Hawthorne effect is quite unlikely because there were many null results between baseline and both the placebo and experimental intervention phases. Despite the small sample size, one would expect the opposite from a Hawthorne effect. Furthermore, the objective sleep physiology data should not be vulnerable to the Hawthorne effect.

Another study limitation is the grouping of strategies to help one adapt to rotating shiftwork rather than using one specific approach. However, we sought to maximize the potential intervention effect given our small sample size. Also, we based the measure of strategy use upon self-report via logbooks rather than direct observation. Although it was stressed that the faculty not use these strategies during the active placebo phase, data were not collected to see whether they persisted in using the strategies. We believed that if the faculty were repeatedly asked whether they were using the strategies during the active placebo phase, they would have been more apt to use them consciously or subconsciously.

Further difficulties in studying the effects of our intervention occurred due to the unpredictable responsibilities of EPs. The activity of the ED and the amount of external stimuli from other staff members clearly limited the ability to strictly standardize the data collection times and settings. These uncontrolled factors could have masked differences in alertness and performance during testing. Also, with a sample size of 6, individual differences may have been a source of variance.

In an effort to use realistic tests, 2 performance tests were created that simulated subjects' actual responsibilities. The 75% agreement of certified cardiologists' interpretations of ECGs and rhythms was reasonable validation for this measure. However, interrater discongruence by the cardiologists on 25% of the ECGs increased the options for "correct" answers. The subjects' improvement in intubation speed during the later parts of their shifts could have been due to a practice effect of intubating the mannequin several times during a single shift.

The question of order effect was addressed by the use of counterbalancing in the within-subjects design. Since the subjects had been in medicine for a decade, they had learned many of the suggested countermeasures by trial and error and had already incorporated these principles into their daily habits. It may have been difficult for the subjects to give up the strategies during the active placebo and this may have decreased the difference between the 2 conditions. This limitation could be avoided in the future if a similar intervention is done with a younger group such as residents or medical students who have not developed strategies to overcome the negative aspects of shiftwork. Residents are consistently more sleep-deprived than attendings, so improving their schedule and implementing the intervention package may be even more difficult, although the benefits reaped may be greater. However, the transitory employment and rotating clinical rotations of residents may make a long-term study of sleep habits and performances less practical.

CONCLUSIONS

The implementation of a broad-based intervention into the realistic setting of an ED was successfully accomplished. The study confirms previous reports that working night shifts results in negative changes in physicians' moods and performance of sustained tasks and intubation speed. Although some improvements in sleep quantity and quality were noted with our broad-based intervention for enhancing physician adaptation to night shifts and the participants subjectively reported that the experimental intervention improved their lives, the study did not have enough power to conclusively demonstrate that the intervention was effective.

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