The NEW ENGLAND JOURNAL of MEDICINE

established in 1812 | october 28, 2004 | vol. 351 no. 18

Effect of Reducing Interns' Weekly Work Hours on Sleep and Attentional Failures

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ABSTRACT

BACKGROUND

Knowledge of the physiological effects of extended (24 hours or more) work shifts in postgraduate medical training is limited. We aimed to quantify work hours, sleep, and attentional failures among first-year residents (postgraduate year 1) during a traditional rotation schedule that included extended work shifts and during an intervention schedule that limited scheduled work hours to 16 or fewer consecutive hours.

METHODS

Twenty interns were studied during two three-week rotations in intensive care units, each during both the traditional and the intervention schedule. Subjects completed daily sleep logs that were validated with regular weekly episodes (72 to 96 hours) of continuous polysomnography (r=0.94) and work logs that were validated by means of direct observation by study staff (r=0.98).

RESULTS

Seventeen of 20 interns worked more than 80 hours per week during the traditional schedule (mean, 84.9; range, 74.2 to 92.1). All interns worked less than 80 hours per week during the intervention schedule (mean, 65.4; range, 57.6 to 76.3). On average, interns worked 19.5 hours per week less (P<0.001), slept 5.8 hours per week more (P<0.001), slept more in the 24 hours preceding each working hour (P<0.001), and had less than half the rate of attentional failures while working during on-call nights (P=0.02) on the intervention schedule as compared with the traditional schedule.

CONCLUSIONS

Eliminating interns' extended work shifts in an intensive care unit significantly increased sleep and decreased attentional failures during night work hours.

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N Engl J Med 2004;351:1829-37.

The Accreditation Council for Graduate Medical Education (ACGME) has recently limited work hours for U.S. medical residents to less than 320 hours in a four-week period, with up to 32 additional hours for programs granted exceptions.[1] Largely missing from the debate[2-11] are objective data quantifying trainees' actual work and sleep hours. Subjective reports indicated that, before the new regulations were implemented, some trainees worked up to 140 hours per week,[12-16] although the validity of such reports has been questioned.[3,17]

Although residency training may restrict participants' opportunities to sleep, given that there are only 168 hours in a week,[14] some have suggested that reducing residents' work hours may not increase their duration of sleep.[13,18] Neither the restrictions implemented by the ACGME nor reforms proposed by other proponents of reducing the number of hours worked by residents[2] were evaluated a priori to determine their effect on sleep or work-related performance.

As part of the Harvard Work Hours, Health and Safety Study, the Intern Sleep and Patient Safety Study was designed to quantify work hours, sleep, and the rates of medical errors among interns working in critical care units. In the present study, we tested the hypothesis that eliminating interns' extended work shifts would significantly increase their duration of sleep and reduce attentional failures, as compared with the traditional work schedule. In another article in this issue of the *Journal*, Landrigan and colleagues[19] tested the hypothesis that eliminating extended work shifts would significantly decrease the rates of medical errors among interns.

METHODS

The objectives of the study were to quantify work hours and sleep in interns during a traditional schedule; compare subjective reports of work hours and sleep with simultaneous, independent, objective measures; and measure the effect of an intervention designed to eliminate extended work shifts on physicians' work hours, sleep, and attentional failures. Details of the methods are provided in the Supplementary Appendix (available with the full text of this article at www.nejm.org).

SUBJECTS

In March 2002, all 72 persons who had accepted a position in the internal-medicine residency training program (postgraduate year 1) at Brigham and Women's Hospital in Boston were asked to participate in the study (Fig. 1). Fifty-one interns volunteered for the study, and the first 24 interns (on the basis of the date the consent form was signed) whose schedule was compatible with the study schedule were enrolled. There were 11 women and 13 men, and the mean (±SD) age was 28.0±2.0 years. The human research committee of Partners Healthcare and Brigham and Women's Hospital approved all procedures, and all participants provided written informed consent.

COVERAGE SCHEDULES

Using a within-subjects design, we studied 20 interns during two three-week rotations in the medical intensive care unit (MICU) and coronary care unit (CCU) while they followed a traditional schedule with extended work shifts of 30 consecutive hours scheduled every other shift and an intervention schedule in which work shifts were a maximum of 16 consecutive hours scheduled. The remaining four subjects were studied while they followed a pilot intervention schedule that was discontinued after the first MICU rotation (data not included). During the traditional schedule, three interns provided continuous coverage on a three-day cycle, officially consisting of a day shift (approximately 7 a.m. to 3 p.m.) on day 1 followed by an extended work shift from 7 a.m. on day 2 to noon on day 3, although in actual practice, interns often worked beyond those hours (Fig. 2A). The interns staffed weekly ambulatory clinics when the clinics coincided with day 1 or day 3, and the average scheduled hours totaled approximately 77 to 81 hours per week, depending on the clinic assignment. During the intervention rotation, four interns provided continuous coverage on a four-day schedule, consisting of a standard day shift (approximately 7 a.m. to 3 p.m.) on day 1, "day call" on day 2 from 7 a.m. to 10 p.m. (the first half of the traditional extended work shift), and "night call" on days 3 through 4, from 9 p.m. on day 3 to 1 p.m. on day 4 (the second half of the traditional extended shift), although the interns often worked longer than their scheduled hours on the intervention schedule as well (Fig. 2C). The maximal scheduled duration of a shift was 16 hours. Interns staffed clinics only during day shifts (day 1); thus, the maximal number of scheduled work hours was approximately 60 to 63 hours per week. To counter the effects of extended wakefulness before night work, interns were advised to take an afternoon nap before starting the night call. During the traditional schedule, no such opportunity was available, owing to the requirement to work continuously during the day and night. In the two weeks before each study rotation, the interns worked primarily on an ambulatory clinic rotation.

WORK-HOUR MEASUREMENTS

Interns recorded work hours in a daily log. Study staff also kept independent logs of interns' work hours, whenever possible. Concurrent data were available for 75 percent of work shifts and were significantly correlated in all subjects (mean r=0.98; range, 0.91 to 0.99; P<0.001 by Student's t-test). Weekly work hours were compared between the two schedules by within-subjects paired Student's t-tests. The proportion of hours worked during extended shifts was compared between rotations by means of a chi-square test.

SLEEP MEASUREMENTS

Interns completed a daily log recording details of sleep episodes. At least three days per week during MICU or CCU rotations, interns underwent continuous ambulatory polysomnographic (Vitaport-2/3, TEMEC Instruments) monitoring[20] while at work or at home. On the basis of an average (±SD) of 334.5±33.4 hours of interpretable polysomnographic recordings with concomitant sleep logs per subject, 95.6±1.8 percent of the 30-second intervals, termed "epochs" (as defined in the Supplementary Appendix), during which polysomnographic data were scored concurred with the sleep-log entries. The total sleep time per rotation derived from the two methods was also correlated across the 20 interns (r=0.94, P<0.001).

The weekly duration of sleep was compared between the two schedules by within-subjects paired Student's t-tests. The number of hours of sleep in the preceding 24 hours was calculated for each work hour and compared between rotation types by means of a chi-square test.

ATTENTIONAL-FAILURE MEASUREMENTS

Attentional failures were identified by means of continuous electrooculography (EOG) and defined as intrusion of slow-rolling eye movements into polysomnographically confirmed episodes of wakefulness during work hours. The number of slow eye movements recorded during all waking polysomnographic epochs was determined by a single scorer according to established criteria in an unblinded fashion.[21] Results were then validated in a blinded fashion by an independent scorer who compared them with the rates recorded from 9 p.m. to 3 p.m. in a subgroup (10 percent) of EOG recordings (r=0.94, P<0.001). The number of 30-second EOG epochs containing at least one slow eye movement was expressed as a percentage of a subject's time awake and compared within subjects at corresponding clock times between the two schedules by means of Student's t-test.

All statistical tests were two-tailed. Error estimates represent the standard deviation of the mean unless specified.

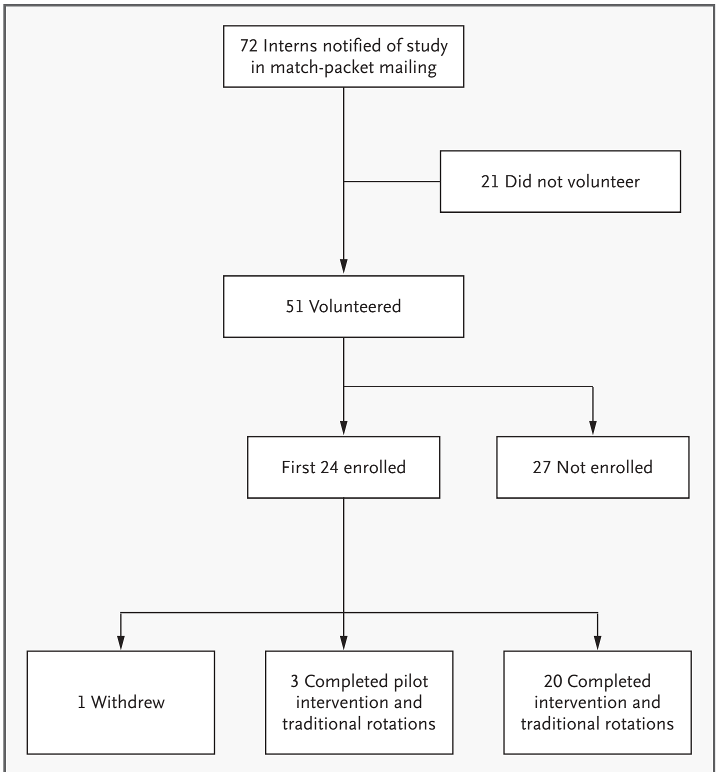


Figure 1. The Recruitment Procedure.

RESULTS

WORK HOURS

All 20 interns worked longer during the traditional schedule (mean, 84.9±4.7 hours per week; range, 74.2 to 92.1) than during the intervention schedule (mean, 65.4±5.4 hours per week; range, 57.6 to 76.3; P<0.001) (Fig. 3A). Seventeen of the 20 interns

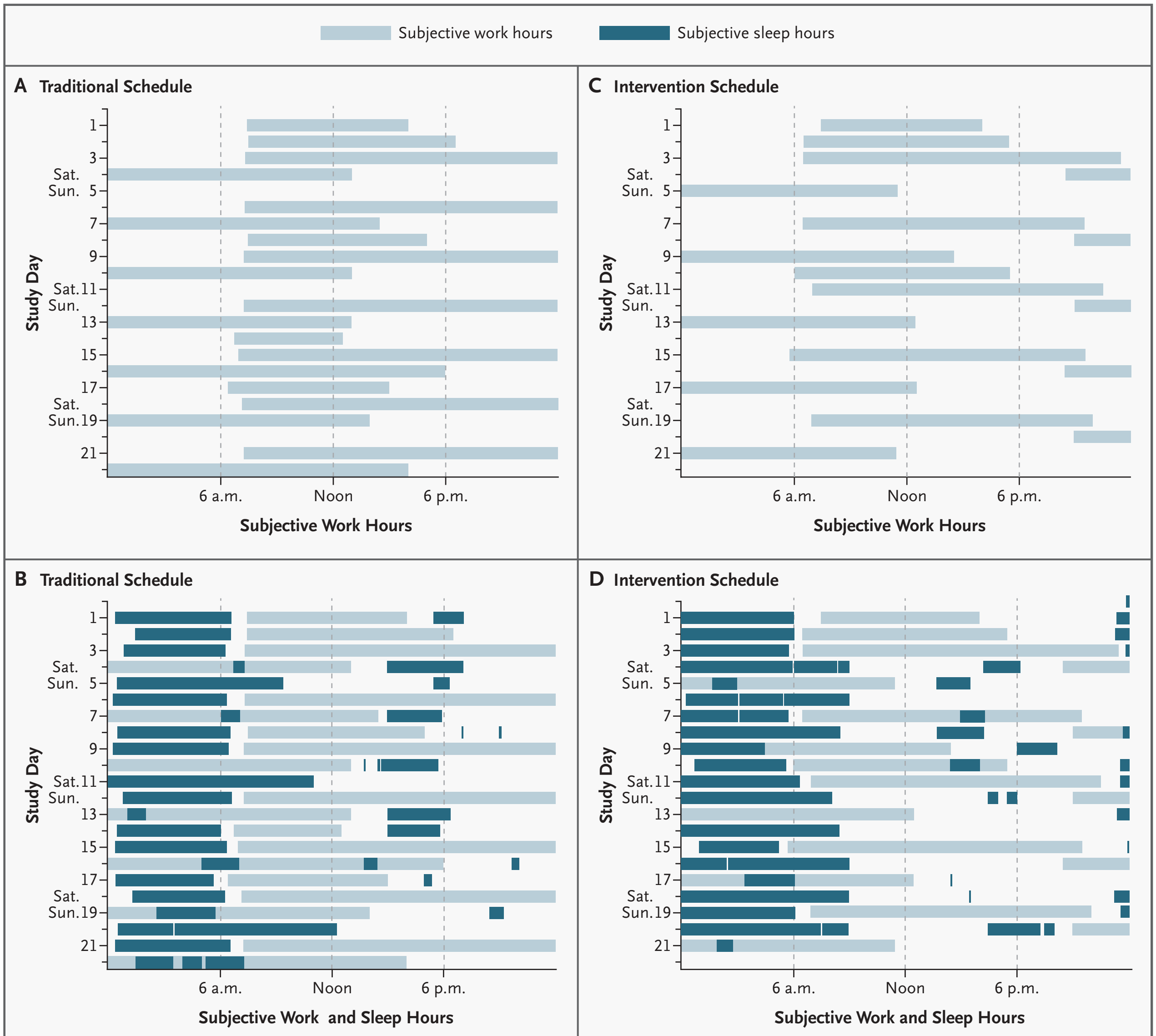


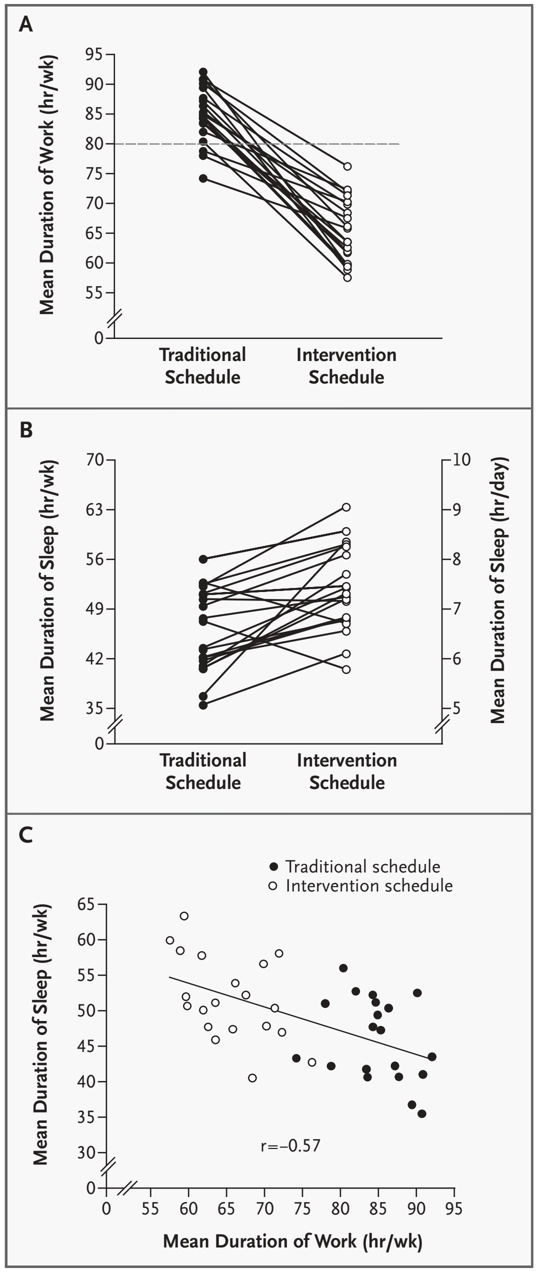
Figure 2. The Pattern of Subjective Work Hours and Subjective Hours of Sleep Reported by a Single Intern Working in an ICU during the Traditional Schedule (Panels A and B) and the Intervention Schedule (Panels C and D).

Sequential study days are shown on the ordinate of each panel, with weekend days included for reference, and clock time is shown on the abscissa. Both work rotations started on a Wednesday (day 1) and ended on a Tuesday (day 21) unless the last work shift was scheduled to be overnight (e.g., days 21 through 22 in Panel A). This intern worked an average of 83.4 hours per week during the traditional schedule, as compared with 62.6 hours per week during the intervention schedule. In Panels B and D the subjective sleep times are superimposed over work hours, including the hours the intern spent asleep while at the hospital (e.g., approximately 6 a.m. on days 4, 7, and 16 in Panel B). This intern slept 41.8 hours per week during the traditional schedule and 47.8 hours per week during the intervention schedule.

worked more than 80 hours per week during the traditional schedule, whereas all interns worked less than 80 hours per week during the intervention schedule (Fig. 3A). The average difference in work hours was 19.5 hours per week (range, 8.4 to 32.4), or 69.2 hours per rotation (range, 26.3 to 107.3). There was no correlation between an individual intern's work hours during the pre-ICU ambulatory clinic rotation and his or her subsequent ICU rotation (r=0.20, P=0.44 during the traditional schedule; r=−0.20, P=0.43 during the intervention schedule) or between an individual intern's

Figure 3. Subjective Mean Hours of Work per Week (Panel A), Duration of Sleep (Panel B), and the Relationship between the Duration of Work and the Duration of Sleep (Panel C) for 20 Interns during the Traditional Schedule and the Intervention Schedule.

All subjects worked less during the intervention schedule than during the traditional schedule (mean decrease, 19.5 hours per week) (Panel A). All but three subjects worked more than 80 hours per week during the traditional schedule, whereas the maximal number of hours worked during the intervention schedule was 76.3 hours. All but three subjects slept more during the intervention schedule, with the group averaging 5.8 hours more sleep per week (Panel B). The duration of work and the duration of sleep were inversely correlated (r=–0.57, P<0.001) (Panel C) during the traditional and intervention schedules, with the best-fit regression predicting a 19.2-minute loss of sleep per week for every additional hour of work per week.



two ICU rotations (r=0.05, P=0.85). Additional results are provided in Table 1 of the Supplementary Appendix.

During the traditional rotation, over half of work shifts (133 of 223, or 60 percent) were extended (more than 24 hours) and 84 percent of work hours (4255 of 5036) occurred during these shifts (Fig. 4A) — with 21 percent of these work hours logged after more than 24 hours of continuous duty. The intervention schedule had no extended work shifts (Fig. 4B), and 96 percent of work hours occurred within the 16 hours scheduled, in contrast to the traditional schedule, in which only 58 percent of work hours occurred within the first 16 hours on duty.

DURATION OF SLEEP

Interns slept an average of 45.9±5.9 hours per week (6.6±0.8 hours per day) during the traditional schedule, 5.8 fewer hours per week than during the intervention schedule (mean, 51.7±6.0 hours of sleep per week, or 7.4±0.9 hours per day; P<0.001). All but three interns slept more during the intervention schedule than during the traditional schedule (Fig. 3B).

DURATION OF WORK AND SLEEP

The weekly durations of sleep and work were significantly inversely correlated (r=–0.57, P<0.001), with a predicted loss of 19.2 minutes of sleep per week for each additional hour of work per week (Fig. 3C). During the traditional schedule, 31 percent of work hours were preceded by 4 or fewer hours of sleep in the preceding 24 hours and 19 percent of work hours were preceded by 2 or fewer hours of sleep in the previous 24 hours, as compared with 13 percent and 6 percent, respectively, during the intervention schedule (P<0.001 for both comparisons) (Fig. 4C). The percentage of work hours preceded by more than 8 hours of sleep in the prior 24 hours was 17 percent during the traditional schedule and 33 percent during the intervention schedule (P<0.001) (Fig. 4C). Interns reported

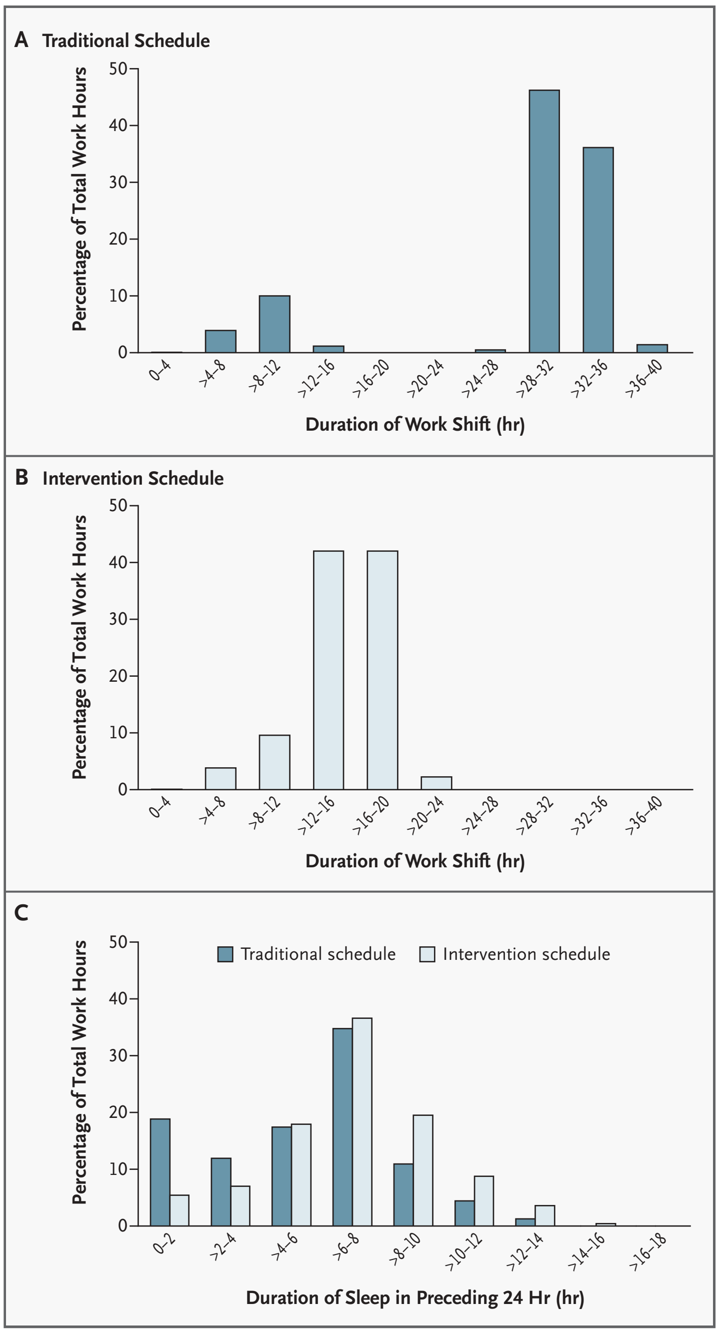


Figure 4. Proportion of Total Work Hours Plotted against the Duration of the Shift during the Traditional Schedule (Panel A) and the Intervention Schedule (Panel B) and the Percentage of Total Work Hours That Occurred after Various Amounts of Sleep in the Preceding 24 Hours (Panel C).

During the traditional schedule, the majority of work hours (84 percent) were during extended work shifts (more than 24 hours) (Panel A), whereas there were no work hours during extended shifts on the intervention schedule (Panel B). Panel C shows the distribution of work hours relative to the duration of sleep in the prior 24 hours for the traditional and intervention schedules. A greater proportion of work hours during the traditional schedule than during the intervention schedule (48 percent vs. 31 percent) were preceded by 6 or fewer hours of sleep in the preceding 24 hours, whereas twice as many work hours were preceded by more than 8 hours of sleep in the preceding 24 hours during the intervention schedule as during the traditional schedule (33 percent vs. 17 percent).

taking a prophylactic nap before night call during the intervention schedule on 69.9±30.8 percent of occasions.

On average, interns slept for 1.76±1.04 hours between 9 p.m. and 8 a.m. during the traditional schedule, significantly longer than they slept while working the corresponding hours during the intervention schedule (1.29±0.90 hours per shift, P=0.02).

ATTENTIONAL FAILURES

Attentional failures occurred at more than double the rate during the night (from 11 p.m. to 7 a.m.) on the traditional schedule as compared with the intervention schedule (P=0.02) (Fig. 5) and 1.5 times the rate during the day (7 a.m. to 10 p.m.) (P=0.07).

DISCUSSION

The elimination of extended work shifts had a significant effect on the number of hours worked by interns, the duration of sleep, and the rate of attentional failures. Eighty-four percent of the work hours on the traditional schedule occurred during extended work shifts (24 hours or more), as compared with 0 percent on the intervention schedule. The traditional schedule had three times as many shifts that were prefaced by fewer than 2 hours of sleep in the preceding 24 hours and more than twice as many attentional failures during night work as did the intervention schedule.

Daily reports, validated by simultaneous independent objective assessments, captured the high degree of variability in work hours and sleep across rotations with greater precision than did residents' estimations of work hours, sometimes covering an entire year or longer, used in previous studies.[12,13,15,16,22] For example, work hours during the pre-ICU clinic rotation averaged 40 hours per week but increased to 85 hours per week during the three-week traditional ICU schedule. The resulting four-week average of 74 hours per week, calculated as specified by the ACGME,[1] means that interns' schedules in high-intensity settings can far exceed the weekly work-hour limits of "no more than 80 hours in *any* week" and "no more than 12 hours of continuous duty" specified by the Association of American Medical Colleges.[23]

The average of 85 hours of work per week during the traditional schedule represented half of the 168 hours available in a week (every other shift on the schedule averaged 32 hours, despite this being termed a "Q3," or "every third night," call schedule) and did not include other work-related activities, such as commuting or studying. With such a large proportion of the available hours used for work, it is not surprising that the amount of time interns spent sleeping was directly related to the duration of work, with approximately one third of the newly available free time on the intervention used for sleep, an increase of nearly an hour per day. Moreover, as compared with their patterns of sleep during the traditional schedule, interns worked half as many shifts during the intervention schedule after having had 4 or fewer hours of sleep in the prior 24 hours and twice as many shifts after having had more than 8 hours of sleep in the preceding day. They also slept significantly less during night work during the intervention schedule. These results demonstrate that interns working on the intervention schedule were less sleep-deprived at work and were more often able to sleep longer during nonwork hours to counteract in part the cumulative and acute performance- and health-related adverse effects of sleep deprivation.[24-28]

The acute and chronic sleep deprivation inherent in the traditional schedule[14] caused a significant increase in attentional failures in interns working at night. The robustness of this result, which was evident in 13 of the 20 interns, is striking, considering the fact that caffeine use, compliance with the protocol, and individual differences in the need for sleep among subjects could not be controlled in this field study. The presence of slow-rolling eye movements during wakefulness is indicative of profound fatigue in both occupational settings[29] and laboratory settings[21] and parallels subjective sleepiness, theta activity on electroencephalography, and impaired neurobehavioral performance[21,29] similar to those observed among subjects in studies of acute and chronic partial sleep deprivation[24,25] and in previous studies of residents.[18,30-33] Slow eye movements are correlated with performance failures on the psychomotor vigilance task[21] and are reduced by treatments that counteract fatigue and thus improve neurobehavioral performance.[34-36] The increased incidence of attentional failures during night work among interns during the traditional as compared with the intervention schedule may impede their ability to care for patients and their education.[27,37] It is noteworthy that interns took prophylactic naps before two thirds of the overnight shifts during the intervention schedule, thereby preemptively attenuating the deleterious effects on alertness and neurobehavioral performance of continuous wakefulness and blunting the circadian performance nadir.[38] Although the relative contribution of these and other factors to the observed improvement cannot be determined from our findings, we believe it unlikely that simply decreasing the number of hours worked in a week without incorporating the underlying principles of sleep physiology would yield a similar increase in sleep or reduction in attentional

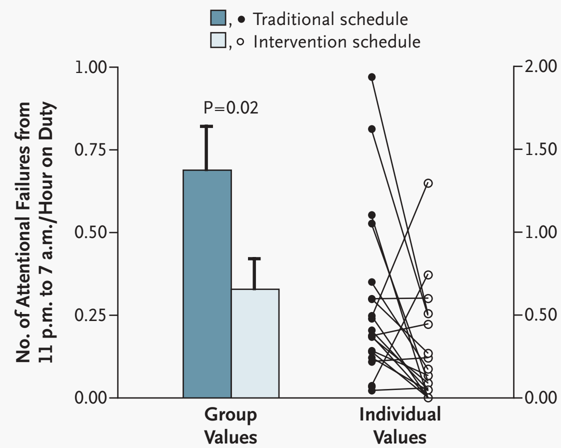


Figure 5. Mean (+SE) Number of Attentional Failures among the 20 Interns as a Group and Individually while Working Overnight (11 p.m. to 7 a.m.) during the Traditional Schedule and the Intervention Schedule.

The number of attentional failures was determined by the presence of at least one electrooculography-derived slow eye movement while the subject was awake and at work. The rate of attentional failures among interns who were working overnight (from 11 p.m. to 7 a.m.) during the intervention schedule (0.33 per hour, or 2.6 attentional failures per intern overnight) was less than half that during the corresponding times on the traditional schedule (0.69 per hour, or 5.5 attentional failures per intern overnight; P=0.02), and a trend (P=0.07) toward a reduction in attentional failures during day and evening call (7 a.m. to 10 p.m.) was also apparent (data not shown). Thirteen of the 20 interns had a decrease in the number of slow eye movements during overnight work on the intervention schedule as compared with the traditional schedule.

failures. For example, changing the frequency of extended work shifts from every other shift to every third shift would be unlikely to cause a similar reduction in attentional failures despite effecting a similar reduction in weekly work hours, because interns would still be required to work extended shifts.

Superimposed on the population effects are interindividual variations in the detrimental effects of sleep restriction. Nearly a quarter of the population,[39] including night-shift workers[40] and residents,[30] is particularly sensitive to sleep loss. This sizable and unidentified proportion of the population may be particularly vulnerable to the effects of extended work shifts and chronic sleep restriction imposed during residency training, possibly unwittingly placing themselves and their patients at markedly increased risk for fatigue-related errors.

The intervention schedule had limitations. Despite the fact that the extended work shift was split in half, most work shifts remained long enough to induce significant decrements in neurobehavioral performance owing to sleep deprivation[21,24] and still exceeded the limits imposed by many other safety-sensitive industries, such as transportation and nuclear power, on the number of consecutive hours of work. Moreover, the interns often had to rise between 4 a.m. and 6 a.m., the time of maximal sleep propensity and efficiency in this age group,[41] to review their patients' progress before morning rounds. Since nearly a third of their work hours (31 percent) were thus preceded by 6 or fewer hours of sleep in the preceding 24 hours, they continued to carry a substantial sleep debt, accounting for the high residual rate of attentional failures on both schedules, even during the day.[22] Furthermore, during both the traditional and the intervention schedule, reported work hours often exceeded both the scheduled weekly hours and the number of consecutive work hours scheduled, owing to the interns' obligation to ensure the continued care of their patients after their own shift was over. Our data on actual work hours reveal that the maximal number of scheduled work hours must be much lower to allow for this inevitability.

Our study provides objectively validated data on work hours, sleep, and attentional failures among medical trainees in situ and quantifies the effects of eliminating extended work shifts on these measures. Our findings may apply not only to residents working in critical care units but also to those on other rotations and specialties and to more senior residents, attending physicians, nurses, and others. Future studies should further evaluate the effects of current working practices on physicians and objectively measure the effect of interventions designed to improve physicians' health and patients' safety.

Supported by a grant (RO1 HS12032) from the Agency for Healthcare Research and Quality (AHRQ), affording data-confidentiality protection by federal statute (Public Health Service Act 42 U.S.C.); a grant from the National Institute of Occupational Safety and Health (RO1 OH07567), which provided a Certificate of Confidentiality for data protection; the Department of Medicine, Brigham and Women's Hospital; the Division of Sleep Medicine, Harvard Medical School; Brigham and Women's Hospital; and a General Clinical Research Center grant (M01 RR02635) from the National Center for Research Resources. Dr. Landrigan is the recipient of an AHRQ career development award (K08 HS13333); Dr. Cronin is the recipient of an AHRQ National Research Service Award (F32 HS14130) and a National Heart, Lung, and Blood Institute fellowship in the program of training in Sleep, Circadian, and Respiratory Neurobiology at Brigham and Women's Hospital (T32 HL079010); Dr. Lockley is the recipient of a traveling fellowship from the Wellcome Trust, United Kingdom (060018/B/99/Z). Dr. Czeisler is supported in part by the National Space Biomedical Research Institute, through NASA (NCC 9-58).

We are indebted to the volunteers, without whom the project could not have been conducted; to the staff of the Coronary Care Unit and Medical Intensive Care Unit, whose cooperation was also vitally important; to those who helped with the design and complex scheduling for the first year of the study discussed herein, Laura K. Barger, Ph.D., M.P.H., DeWitt C. Baldwin, M.D., Michael Klompas, M.D., Marisa A. Rogers, M.D., Jane S. Sillman, M.D., Heather L. Gornik, M.D., Rainu Kaushal, M.D., and the administrative staff of the Internal Medicine Residency Program; to the Division of Sleep Medicine (DSM) technicians Cathryn Berni, Josephine Golding, Mia Jacobsen, Lynette James, and Marina Tsaoussoglou for their dedication and diligence; to Claude Gronfier, Ph.D., and the DSM Sleep Core, particularly Alex Cutler, Gregory T. Renchkovsky, and Brandon J. Lockyer, R.P.S.G.T., and the DSM Director of Bioinformatics, Joseph M. Ronda, M.S., for their expert support; and to Victor J. Dzau, M.D., Anthony D. Whittemore, M.D., Jeffrey Otten, Matthew Van Vranken, Gary L. Gottlieb, M.D., M.B.A., and Joseph B. Martin, M.D., Ph.D., for their support and encouragement of this work.

REFERENCES

1. Common program requirements (resident duty hours). Chicago: Accreditation Council for Graduate Medical Education, February 2003. (Accessed October 4, 2004, at http://www.acgme.org/DutyHours/dutyHoursCommonPR.pdf.)

2. Gaba DM, Howard SK. Fatigue among clinicians and the safety of patients. N Engl J Med 2002;347:1249-55.

3. Steinbrook R. The debate over residents' work hours. N Engl J Med 2002;347:1296-302.

4. Drazen JM, Epstein AM. Rethinking medical training — the critical work ahead. N Engl J Med 2002;347:1271-2.

5. Leape L, Epstein AM, Hamel MB. A series on patient safety. N Engl J Med 2002;347:1272-4.

6. Czeisler CA, Lockley SW, Landrigan CP, et al. Current resident work hours: too many or not enough? JAMA 2002;287:1802-3.

7. Buysse DJ, Barzansky B, Dinges D, et al. Sleep, fatigue, and medical training: setting an agenda for optimal learning and patient care. Sleep 2003;26:218-25.

8. Rosen IM, Shea JA, Bellini LM. Residents' work hours. N Engl J Med 2003;348:665-6.

9. Lowenstein J. Where have all the giants gone? Reconciling medical education and the traditions of patient care with limitations on resident work hours. Perspect Biol Med 2003;46:273-82.
10. Lewis FR Jr. Should we limit resident work hours? Ann Surg 2003;237:458-9.
11. Mullins MD, Mascolo MC. Residents' work hours. N Engl J Med 2003;348:665.
12. Baldwin DC Jr, Daugherty SR, Tsai R, Scotti MJ Jr. A national survey of residents' self-reported work hours: thinking beyond specialty. Acad Med 2003;78:1154-63.
13. Baldwin DC Jr, Daugherty SR. Sleep deprivation and fatigue in residency training: results of a national survey of first- and second-year residents. Sleep 2004;27:217-23.
14. Czeisler CA. Work hours and sleep in residency training. Sleep 2004;27:371-2.
15. Whang EE, Mello MM, Ashley SW, Zinner MJ. Implementing resident work hour limitations: lessons from the New York State experience. Ann Surg 2003;237:449-55.
16. Niederee MJ, Knudtson JL, Byrnes MC, Helmer SD, Smith RS. A survey of residents and faculty regarding work hour limitations in surgical training programs. Arch Surg 2003;138:663-9.
17. Barden CB, Specht MC, McCarter MD, Daly JM, Fahey TJ III. Effects of limited work hours on surgical training. J Am Coll Surg 2002;195:531-8.
18. Veasey S, Rosen R, Barzansky B, Rosen I, Owens J. Sleep loss and fatigue in residency training: a reappraisal. JAMA 2002;288:1116-24.
19. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors among interns in intensive care units. N Engl J Med 2004;351:1838-48.
20. Richardson GS, Wyatt JK, Sullivan JP, et al. Objective assessment of sleep and alertness in medical house staff and the impact of protected time for sleep. Sleep 1996;19:718-26.
21. Cajochen C, Khalsa SBS, Wyatt JK, Czeisler CA, Dijk D-J. EEG and ocular correlates of circadian melatonin phase and human performance decrements during sleep loss. Am J Physiol 1999;277:R640-R649.
22. Howard SK, Gaba DM, Rosekind MR, Zarcone VP. The risks and implications of excessive daytime sleepiness in resident physicians. Acad Med 2002;77:1019-25.
23. AAMC policy guidance on graduate medical education: assuring quality patient care and quality education. Washington, D.C.: Association of American Medical Colleges (AAMC), October 2001. (Accessed October 4, 2004, at http://www.aamc.org/hlthcare/gmepolicy/gmepolicy.pdf.)
24. Van Dongen HPA, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep 2003;26:117-26.
25. Belenky G, Wesensten NJ, Thorne DR, et al. Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. J Sleep Res 2003;12:1-12.
26. Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. Lancet 1999;354:1435-9.
27. Walker MP, Brakefield T, Morgan A, Hobson JA, Stickgold R. Practice with sleep makes perfect: sleep-dependent motor skill learning. Neuron 2002;35:205-11.
28. Cho K. Chronic 'jet lag' produces temporal lobe atrophy and spatial cognitive deficits. Nat Neurosci 2001;4:567-8.
29. Torsvall L, Akerstedt T. Sleepiness on the job: continuously measured EEG changes in train drivers. Electroencephalogr Clin Neurophysiol 1987;66:502-11.
30. Bartel P, Offermeier W, Smith F, Becker P. Attention and working memory in resident anaesthetists after night duty: group and individual effects. Occup Environ Med 2004;61:167-70.
31. Rollinson DC, Rathlev NK, Moss M, et al. The effects of consecutive night shifts on neuropsychological performance of interns in the emergency department: a pilot study. Ann Emerg Med 2003;41:400-6.
32. Howard SK, Gaba DM, Smith BE, et al. Simulation study of rested versus sleep-deprived anesthesiologists. Anesthesiology 2003;98:1345-55.
33. Halbach MM, Spann CO, Egan G. Effect of sleep deprivation on medical resident and student cognitive function: a prospective study. Am J Obstet Gynecol 2003;188:1198-201.
34. Cajochen C, Zeitzer JM, Czeisler CA, Dijk DJ. Dose-response relationship for light intensity and ocular and electroencephalographic correlates of human alertness. Behav Brain Res 2000;115:75-83.
35. Phipps-Nelson J, Redman JR, Dijk DJ, Rajaratnam SM. Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance. Sleep 2003;26:695-700.
36. Neri DF, Oyung RL, Colletti LM, Mallis MM, Tam PY, Dinges DF. Controlled breaks as a fatigue countermeasure on the flight deck. Aviat Space Environ Med 2002;73:654-64.
37. Huber R, Ghilardi MF, Massimini M, Tononi G. Local sleep and learning. Nature 2004;430:78-81.
38. Jewett ME. Models of circadian and homeostatic regulation of human performance and alertness. (Ph.D. thesis. Cambridge, Mass.: Harvard University, 1997.)
39. Van Dongen HPA, Baynard MD, Maislin G, Dinges DF. Systematic interindividual differences in neurobehavioral impairment from sleep loss: evidence of trait-like differential vulnerability. Sleep 2004;27:423-33.
40. Ohayon MM, Lemoine P, Arnaud-Briant V, Dreyfus M. Prevalence and consequences of sleep disorders in a shift worker population. J Psychosom Res 2002;53:577-83.
41. Dijk DJ, Czeisler CA. Paradoxical timing of the circadian rhythm of sleep propensity serves to consolidate sleep and wakefulness in humans. Neurosci Lett 1994;166:63-8.