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

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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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Graduate Medical Education (ACGME) has
recently limited work hours for U.S. medi-
cal 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 debate2-11 are objective data quantifying trainees’
actual work and sleep hours. Subjective reports indi-
cated that, before the new regulations were im-
plemented, 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 par-
ticipants’ opportunities to sleep, given that there
are only 168 hours in a week,14 some have suggest-
ed that reducing residents’ work hours may not in-
crease their duration of sleep.13,18 Neither the re-
strictions implemented by the ACGME nor reforms
proposed by other proponents of reducing the num-
ber of hours worked by residents2 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 work-
ing in critical care units. In the present study, we test-
ed the hypothesis that eliminating interns’ extended
work shifts would significantly increase their dura-
tion of sleep and reduce attentional failures, as com-
pared with the traditional work schedule. In anoth-
er article in this issue of the Journal, Landrigan and
colleagues19 tested the hypothesis that eliminat-
ing extended work shifts would significantly de-
crease 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 sched-
ule; compare subjective reports of work hours and
sleep with simultaneous, independent, objective
measures; and measure the effect of an interven-
tion 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 train-
ing program (postgraduate year 1) at Brigham and
Women’s Hospital in Boston were asked to par-
ticipate in the study (Fig. 1). Fifty-one interns vol-
unteered 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 Health-
care and Brigham and Women’s Hospital approved
all procedures, and all participants provided writ-
ten informed consent.

COVERAGE SCHEDULES
Using a within-subjects design, we studied 20 in-
terns during two three-week rotations in the med-
cal intensive care unit (MICU) and coronary care
unit (CCU) while they followed a traditional sched-
ule with extended work shifts of 30 consecutive
hours scheduled every other shift and an interven-
tion 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 pro-
vided 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 coinci-
ded with day 1 or day 3, and the average sched-
uled hours totaled approximately 77 to 81 hours
per week, depending on the clinic assignment.
During the intervention rotation, four interns pro-
vided 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., “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 sched-
ule as well (Fig. 2C). The maximal scheduled dura-
tion of a shift was 16 hours. Interns staffed clinics
only during day shifts (day 1); thus, the maximal
number of scheduled work hours was approximate-
ly 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 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. 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.

**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

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**Figure 1. The Recruitment Procedure.**
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 ($r=-0.20$, $P=0.43$ during the intervention schedule) or between an individual intern’s
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
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.22,13,15,16,22 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

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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).
EXTENDED WORK HOURS AND ATTENTIONAL FAILURES OF INTERNS

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 schedule14 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 and laboratory settings39 and laboratory settings21 and parallels subjective sleepiness, theta activity on electroencephalography, and impaired neurobehavioral performance21,29 similar to those observed among subjects in studies of acute and chronic partial sleep deprivation24,25 and in previous studies of residents.18,30-33 Slow eye movements are correlated with performance failures on the psychomotor vigilance task21 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...
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, including night-shift workers and residents, 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 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, 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. 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.

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