

When Policy Meets Physiology

The Challenge of Reducing Resident Work Hours

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Considerable controversy exists regarding optimal work hours for physicians and surgeons in training. In a series of studies, we assessed the effect of extended work hours on resident sleep and health as well as patient safety. In a validated nationwide survey, we found that residents who had worked 24 hours or longer were 2.3 times more likely to have a motor vehicle crash following that shift than when they worked < 24 hours, and that the monthly risk of a crash increased by 16.2% after each extended duration shift. We also found in a randomized trial that interns working a traditional on-call schedule slept 5.8 hours less per week, had twice as many attentional failures on duty overnight, and made 36% more serious medical errors and nearly six times more serious diagnostic errors than when working on a schedule that limited continuous duty to 16 hours. While numerous opinions have been published opposing reductions in extended work hours due to concerns regarding continuity of patient care, reduced educational opportunities, and traditionally-defined professionalism, there are remarkably few objective data in support of continuing to schedule medical trainees to work shifts > 24 hours. An evidence-based approach is needed to minimize the well-documented risk that current work hour practices confer on resident health and patient safety while optimizing education and continuity of care.

For The Harvard Work Hours Health and Safety Group
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Considerable controversy exists regarding the optimal work hours of physicians and surgeons in training. It has long been suspected that extended work hours negatively affect medical^{33,34,87} and surgical³⁷ performance, and are possibly damaging to resident health and well-being.^{32,63,70,73,75} Consequently, there have been several sporadic, largely unsuccessful attempts to limit physicians' work hours, often in response to high profile adverse events thought to be related to long work hours.⁶⁸ More recently, guidelines set forth by the Accreditation Council for Graduate Medical Education (ACGME) in the US have reignited this debate and have brought the medical and surgical professions to what is considered by some to be a defining and allegedly disastrous moment in their history.²⁹

In 2003, the ACGME mandated a maximum 80-hour work week, restricted continuous on-call shifts to 30 hours and insisted that residents had one day off per week.¹ Closer inspection of these regulations, however, reveals subtleties that dilute their impact and, in fact, largely permit a continuation of the status quo in most hospitals. For example, the weekly work hour limit is averaged over four weeks, thereby allowing several weeks in excess of 80 hours. An additional 8 hours per week, or 32 hours/4 weeks, can be requested in many specialties, allowing a maximum of 352 hours of work per four weeks. Similarly, days off are also averaged over four weeks and the regulations therefore permit residents to work for 24 consecutive days without a day off, as long as this is followed by four consecutive days off. Moreover, continuous on-call duty hours can be routinely extended past 24 hours with an additional 6 hours allowed for teaching and continuity of care; this "30-hour" limit (24 + 6) is used daily in most medical centers. Altogether, while these limits have attempted to eliminate extreme extended duration work shifts of 32 or more hours that occasionally occurred before their implementation, the ACGME has avoided a paradigm shift in the traditional scheduling of medical residents. Many residency programs have therefore largely

been able to maintain their pre-existing resident on-call schedules with minimal modifications.⁵⁵ Notable exceptions are those surgical training programs which routinely required residents to work 100 or more hours per week;⁸ such programs have had a greater challenge meeting these limits.⁴⁸

In this paper, we review the physiological principles underlying fatigue, and a series of studies by the Harvard Work Hours Health and Safety Group quantifying the negative effects of extended duration work shifts on resident health and patient safety. We found that residents who had worked 24 hours or longer were 2.3 times more likely to have a motor vehicle crash following that shift than when they worked < 24 hours, and that the risk of a crash increased by 16.2% per month after each extended duration shift. We also found in a randomized trial that interns working a traditional on-call schedule slept 5.8 hours less per week, had twice as many attentional failures on duty overnight, and made 36% more serious medical errors and six times more serious diagnostic errors than when working on a schedule that limited continuous duty to 16 hours. Furthermore, we review the need for additional objective research in this area to ensure that future policy developments are based on scientific evidence rather than subjective opinion.

Principles of Sleep Medicine Underlying Fatigue

It is beyond dispute that sleep deprivation adversely affects safety and performance. In many other safety-orientated industries, the deleterious effects of extended duty hours and working at night have been recognized and addressed. The public also readily understands the concept that fatigue increases and performance worsens with increasing hours awake. In fact, 86% of those who responded to a National Sleep Foundation survey reported that they would likely feel anxious about their safety if they learned their surgeon had been on duty > 24 hours, with 70% likely to ask for a different doctor and 60% assuming that the procedure was unlikely to go well.⁶⁰ During the past 30 years there have been considerable advances in the understanding of the neurobiology of sleep and the rhythmic processes underlying sleep patterns, and there now exist a multitude of studies quantifying the negative impact of sleep loss and shift work on short-term fatigue, performance, and learning,^{24,76} and more recently on longer-term health and metabolic consequences.^{4,49,74}

There are four major physiological determinants of alertness and performance: circadian phase, number of hours awake, nightly sleep duration, and sleep inertia. The detrimental effects of each of these four factors are exacerbated by the extended on-call shifts experienced by residents and, consequently, their performance is likely to be degraded (Fig 1). First, residents regularly work during the

Physiological Consequences of Healthcare Provider Schedules

Biological Time of Day (circadian phase)	Misalignment of circadian phase
Number of Hours Awake	Acute total sleep deprivation scheduled frequently
Nightly Sleep Duration	Chronic partial sleep deprivation resulting in cumulative sleep debt
Sleep Inertia	Performance often required within minutes of awakening

Fig 1. Physiological consequences of current resident schedules

biological night when the endogenous drive for alertness is lowest. Second, extended on-call shifts demand long continuous episodes of wakefulness that induce fatigue. Third, residents are regularly exposed to chronic partial sleep deprivation for many months at a time as they repeatedly fail to gain adequate recovery sleep after extended shifts. Finally, residents who do manage to sleep for a few minutes when on-call are often asked to perform emergent actions immediately upon awakening when sleep inertia is maximal.

Circadian rhythms

The daily 24-hour rhythm in alertness and performance is driven by an endogenous circadian pacemaker situated in the suprachiasmatic nuclei (SCN) of the hypothalamus, with the maximal drive for alertness emanating from the pacemaker during the biological day, and maximal drive for sleepiness during the biological night (Fig 2). The adverse effects of attempting to maintain wakefulness during the biological night have measurable consequences, as illustrated by the elevated rate of single-vehicle truck accidents at night compared to daytime accidents,⁵⁹ and the increase in work-related accidents by night-shift workers compared to day workers.³¹ Furthermore, misalignment of the sleep-wake cycle and the circadian pacemaker greatly affects the quality and quantity of sleep attained and subsequently impairs recovery.^{17,21} A sleep opportunity starting at 11pm will lead to more consolidated and extended sleep than the same opportunity at 11 am.

Number of hours awake

In laboratory and field studies conducted among medical and non-medical personnel, increased time awake has repeatedly been proven to lead to decreased alertness and poorer performance. Acute continuous sleep deprivation

has a profound impact on fatigue and, under laboratory conditions, alertness and performance decline in a sigmoidal manner, at least over the first 50 hours of wakefulness.⁴⁴ Notably, impairment of performance has been equated to that associated with blood alcohol concentration^{6,18} with cognitive performance after 19 hours of sustained wakefulness equivalent to a 0.05% blood level, and after 24 hours equal to approximately 0.10% blood alcohol concentration.¹⁸ Under real-world conditions, it is well documented that the risk of fatigue-related fatal truck crashes increases with increased hours driving²⁰ and consequently federal regulations limit the number of consecutive hours that truckers can drive; there is a greater than 15-fold increase in the risk of a fatigue-related fatal crash after more than 13 hours awake compared to the first hour.²⁰

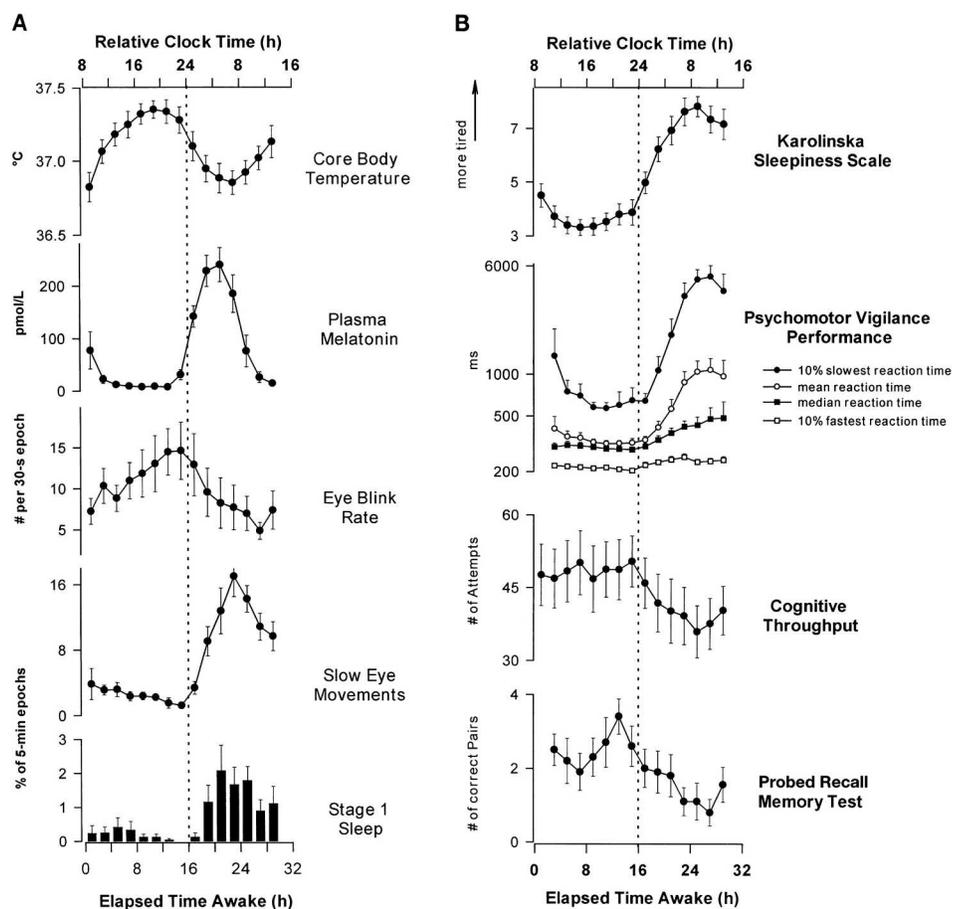
The interaction of these circadian and homeostatic processes, quantified in laboratory studies,²² is exacerbated during traditional resident schedules (Fig 3).¹³ As de-

scribed above, the circadian drive for sleep is maximal toward the end of the night (Fig 2) and, as also described above, increased time spent awake increases fatigue. A resident beginning their 30-hour extended duration shift beginning at 7:00 am will, during and after their night on-call, not only work through their circadian nadir but simultaneously will have been awake for 24 hours or more, vastly amplifying the risk of a fatigue-related lapse of attention during this critical zone of vulnerability (Fig 3).¹³ Whereas federal regulations limit the number of consecutive hours that truck drivers can drive or pilots can fly to reduce this risk, postgraduate medical professionals are currently allowed to work, and to drive after their shifts, during this particularly susceptible time.

Chronic partial sleep deprivation

Under normal conditions, the sleep pressure accumulated during wakefulness is dissipated during sleep to the extent

Fig 2A–B. Endogenous circadian rhythms in human physiology and subjective and objective correlates of alertness. Ten subjects were studied for up to 32 hours of continuous wakefulness after waking at their habitual time while supervised under constant conditions (posture, lighting, nutrient intake; see¹² for details). (A) The endogenous fall in core body temperature and rise in the sleep-promoting hormone melatonin in the late evening (upper panels) are accompanied by a simultaneous increase in polysomnographically-derived eye blink rate, slow rolling eye movements and frank Stage 1 sleep (lower panels), measures considered reliable physiological markers of fatigue. (B) Subjective ratings of sleepiness also increase at this time (upper panel), and psychomotor performance, cognitive throughput and short-term memory begins to deteriorate (lower panels). Subjective and objective measures of sleepiness are maximal, and performance is worst, during the early hours of the morning before gradually improving (although not to levels equivalent to 24 hours earlier) as the circadian drive for alertness increases again. Although average reaction times at the circadian low point average approximately 1 second, the slowest 10% of responses average nearly 6 seconds before the subject reacts to a visual stimulus (second panel down in column B) and, in a real-world environment, could represent a significant lapse of attention, for example while driving or performing surgery. Reproduced with permission from C Cajochen, SB Khalsa, JK Wyatt, CA Czeisler, D-J Dijk. EEG and ocular correlates of circadian melatonin phase and human performance decrements during sleep loss. *Am J Physiol.* 1999;277:R640–R649.



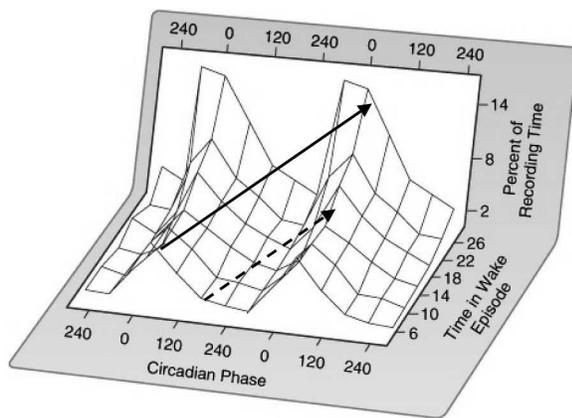


Fig 3. Interaction of circadian phase and duration of wakefulness on waking function. The rate of slow-rolling eye movements, a reliable marker of fatigue,^{12,53} was measured during a specialized laboratory protocol designed to separate the circadian and homeostatic contribution to waking function.¹³ Circadian phase (and relative time of day; 0° ≡ 6:00 am, 120° ≡ 2 pm, 240° ≡ 10:00 pm) is plotted on the x axis, increasing time awake on the y axis and the percent of electrooculogram recording time containing slow-rolling eye movements plotted on the z axis. There is a clear circadian rhythm in the rate of slow eye movements, with maximal fatigue in the early morning. There is also an increase in the rate of slow eye movements with increasing time awake. The interaction between these two processes is indicated by the two example trajectories shown, illustrating two potential resident shifts. The solid arrow indicates the evolution of fatigue of an individual waking at 6:00 am and working an extended duration work shift for the next 24 hours. Fatigue remains fairly stable for the first ~16–18 hours after which it rapidly increases as increased time awake coincides with the endogenous circadian decline in alertness to potentially dangerous levels. The dotted arrow shows fatigue for someone working overnight having had a sleep prior to starting the night shift. While fatigue also deteriorates with increased time awake, the later time of day at which the wake episode starts prevents the cumulative interaction between time awake and adverse circadian phase; even if the individuals remain awake all night, they never reach as high a level of fatigue during the early hours as the resident on duty continuously. Modified with permission from Czeisler CA, Buxton OM, Khalsa SBS. The human circadian timing system and sleep-wake regulation. In: Kryger MH, Roth T, Dement WC, eds. *Principles and Practices of Sleep Medicine*, 4th ed. Philadelphia, PA: W.B. Saunders Company; 2005:375–394.

that alertness is restored to near-maximal levels upon awakening, largely through homeostatic regulation of slow-wave (stage 3/4) sleep.¹⁰ Several lines of evidence suggest that young adults would sleep ~8.4–8.6 hours per night if given sufficient opportunity,^{67,85} far more sleep than is obtained by similar-aged residents.^{8,53,73} Repeated failure to obtain sufficient sleep to fully recover from the previous wake episode has a cumulative detrimental effect on alertness and performance that increases linearly with

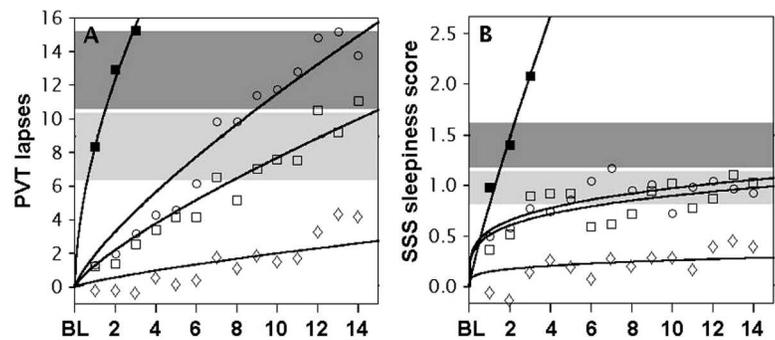
sleep loss (Fig 4).⁷⁷ After less than two weeks with only 6 hours in bed per night, performance levels are equivalent to those observed after 24 hours of acute sleep deprivation (Fig 4).⁷⁷ At four hours in bed per night, it takes only seven days to reach that level and after two weeks, performance is equivalent to 48 hours without sleep. Current resident schedules thus often lead to chronic partial sleep deprivation.⁷³

Sleep inertia

The fourth fatigue-related factor affecting performance is the phenomenon of sleep inertia. Regardless of the timing or duration of sleep, alertness and performance are impaired upon waking. The “grogginess” experienced after waking up does dissipate rapidly; although the effects of sleep inertia are most severe in the first 15–30 minutes after awakening, it may take as long as 1–2 hours to realize a fully alert state.⁴⁵ Unfortunately, the first few minutes are precisely the time during which residents must make critical decisions when awakening in response to an emergent page, greatly increasing the risk of a fatigue-related error.⁷¹

While the fundamental principles underlying sleep and fatigue have primarily been examined under laboratory conditions, there are many complementary examples of the same processes affecting resident performance, health and well-being.^{30,35,65,79} As long as 30 years ago it was recognized that highly sleep-deprived physicians made more errors³³ and performed surgery at an inferior level³⁷ compared to better rested ones. More recently, simulated surgical performance was found to take longer and be of poorer quality and efficiency after a 17 hour overnight call than prior to the call.³⁹ Not all studies appear to be consistent, however. For example, a recent examination of cardiac surgery outcomes in the previous decade showed no differences in operative efficiency, morbidity or mortality for operations performed by residents retrospectively designated as sleep-deprived or non-sleep-deprived.²⁶ Unfortunately, this study did not use validated instruments to determine sleep deprivation or work hours and, while categorizing surgeons into sleep-deprived and non-sleep-deprived groups based on the timing of cases may appear to be reasonable, this approach fails to recognize the major role that chronic sleep deprivation plays in determining fatigue and which was likely to be high in both groups. Furthermore, the study was not sufficiently powered to detect a difference between the sleep-deprived and non-sleep deprived groups due to the relatively low error and mortality rates described. Such confounds underscore the need for prospective research using validated methods to determine the contribution of fatigue to medical and surgical performance. Collectively, however, the weight of

Fig 4. Effect of different amounts of acute and chronic partial sleep deprivation on alertness and performance.⁷⁷ The daily averages from tests performed every two hours (7:30–23:30 h) for the number of lapses on the Psychomotor Vigilance Task (PVT) (panel A) and subjective alertness (Stanford Sleepiness Scale, SSS) (panel B) are shown for subjects undergoing 88 hours of sleep deprivation (■; n = 13 M; 27.3 ± 4.6 yrs), or given 8 hours (◇; n = 9, 7 M; 24.1 ± 2.2 yrs), 6 hours (□; n = 13, 10 M; 30.1 ± 4.5 yrs) or 4 hours (○; n = 13, 12 M; 27.7 ± 5.4 yrs) time in bed per night for 14 days. Performance and alertness were maintained at baseline levels in those with 8 hours sleep opportunity per night in bed. Performance deteriorated in both the 6- and 4-hour sleep groups such that after 14 days, the 6-hour sleep group performed at an equivalent level to those kept awake for 24 hours continuously, and the 4-hour group was performing at the same level as someone kept awake for three whole days (panel A). Subjective sleepiness ratings, however, did not deteriorate in parallel with performance and both the 6- and 4-hour sleep groups reporting maximal sleepiness approximately equivalent to 24 hours of acute sleep deprivation. These results indicate that residents who have less than 8 hours sleep per night are likely to experience deterioration in their performance due to chronic partial sleep deprivation not represented by their own perception of how sleepy they are. Reproduced with permission from HP Van Dongen, G Maislin, JM Mullington, DF Dinges. 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;26:117–126.



current evidence strongly suggests that resident on-call schedules cause fatigue and impair performance.^{30,35,65,79}

A potentially important area of research applicable to medical and surgical resident education is the emerging role of sleep on learning, particularly motor learning, and memory.⁷⁶ A major concern of limiting resident work hours is the perceived reduction in educational opportunities.⁵⁵ Although the *raison d'être* of residents is to receive graduate education, it can be argued that residents provide an inexpensive labor source, the advantages of which are multiplied by permitting excessive work hours. Current resident schedules provide many experiential opportunities, but are not necessarily designed to optimize learning during these experiences. It is hard to learn anything when sleeping through grand rounds post-call, and even more active learning experiences (eg, time in the operating room) are likely to be of lower educational value when residents are sleep-deprived. The role of sleep on residents' learning and consolidation of memory has recently shed light on the educational risks of sleep deprivation.²⁵ Of particular relevance to surgical residents are a series of papers showing that visual discrimination, motor learning and insight are dependent on adequate sleep following the initial learning opportunity.^{76,81–83} Failure to sleep the night after learning a task, or having insufficient duration of a particular sleep stage, may impair residents' ability to consolidate learning about certain procedures and subsequently make improvements.^{41,83} Although not all tasks exhibit this phenomenon, the potential adjunct role for sleep to facilitate learning in residents, or act as a barrier if sleep is inadequate, demands further investigation.

Harvard Work Hours Health and Safety Group

In 2002, the Harvard Work Hours Health and Safety Group embarked on a series of studies to contribute objective data to the debate concerning resident work hours. We aimed to test the hypotheses that extended work hours would have a negative effect on residents' sleep, performance and health, and patient safety. The first results were recently published^{9,51,53} and the major findings are reviewed herein.

Nationwide survey of sleep, work hours and motor vehicle crashes

In the residency year prior to publication of the ACGME guidelines on duty hours, we conducted a prospective nationwide survey of 2737 PGY-1 residents (53% female, mean age ± SD = 28.0 ± 3.9 yrs).⁹ Medical residents represented 79% of the cohort, 11% were in surgical programs and 10% were in other or non-specified specialties; 85% were US medical school graduates. Using a web-based survey tool, volunteers completed a total of 17,003 monthly reports between June 2002 and May 2003 about their sleep, work hours and extended duration work shifts, motor vehicle crashes and near-miss incidents, and self-reported attentional failures while driving, among 60 other questions. Volunteers from those who were matched to a residency by the National Resident Matching Program or who were graduates of US medical schools were invited to participate by e-mail.

We employed a series of validation procedures to ensure data collected through this survey methodology were

accurate. Firstly, a random selection of 7% of participants completed daily work hour and sleep diaries for at least 3 of the 4 weeks requested, a method which we had previously shown correlated highly ($r \geq 0.98$) with work hour reports from continuous observation and polysomnographically-determined sleep, respectively.⁵³ The number of work hours reported on the survey per month (mean \pm SD = 249.8 ± 75.3 h) correlated with the daily work hour diaries (244.0 ± 69.3 h) ($r = 0.76$, $p > 0.001$, $n = 192$) and the number of extended shifts reported by the two methods (3.6 ± 3.3 and 3.5 ± 2.8 , respectively) ($r = 0.94$, $p < 0.001$, $n = 40$).⁹

Secondly, we requested additional documentation in support of all reported motor vehicle crashes. A police report, an insurance claim, a repair record or photograph of the damaged vehicle, a medical record or a written description of the crash was obtained for 82% of all reported crashes.

PGY-1 residents reported being in the hospital for 70.7 ± 26.0 hours per week, and asleep for 3.2 ± 4.2 hours of that time, and averaged 6.5 ± 4.0 days off per month (Fig 5). The frequency of extended duration work shifts (> 24 h) was 3.9 ± 3.4 per month and the mean duration of each extended duration work shift was 32.0 ± 0.7 hours. More than 200 monthly surveys reported shifts exceeding 40 hours, and working after more than 40 hours without sleep was reported more than 1000 times, representing a substantial proportion of the shifts. Most of the extended shifts (86%) had no ‘night-float’ coverage and the mean maximal hours of continuous wakefulness reported was 25.3 ± 8.3 hours. Provision of a night-float had little impact, as we have also previously observed,⁷² and residents with night-float coverage slept only slightly (but significantly) longer on-call (3.2 ± 1.6 hours) than those without coverage (2.6 ± 1.7 hours),

A total of 320 motor vehicle crashes were reported and 40% occurred on the commute from work. Of the 320 crashes, 133 were considered serious (as defined by requiring an Emergency Room visit, causing $> \$1000$ in damages, and/or filing a police report). Using a within-person case-crossover design, we assessed the number and proportion of crashes and near-miss incidents that occurred following an extended duration work shift compared to those following a non-extended shift for each subject. The Mantel-Haenszel odds ratio (OR \pm 95% confidence limit) for a crash on the commute after an extended shift was 2.3 (1.6–3.3) ($p < 0.001$) and 5.9 (5.4–6.3) for a near-miss ($p < 0.001$). A prospective Poisson regression analysis of the association between the mean number of scheduled extended duration work shifts per month and the subsequent occurrence of crashes demonstrated a linear relationship; each extended duration work shift that was scheduled per month increased the rate of any crash by an

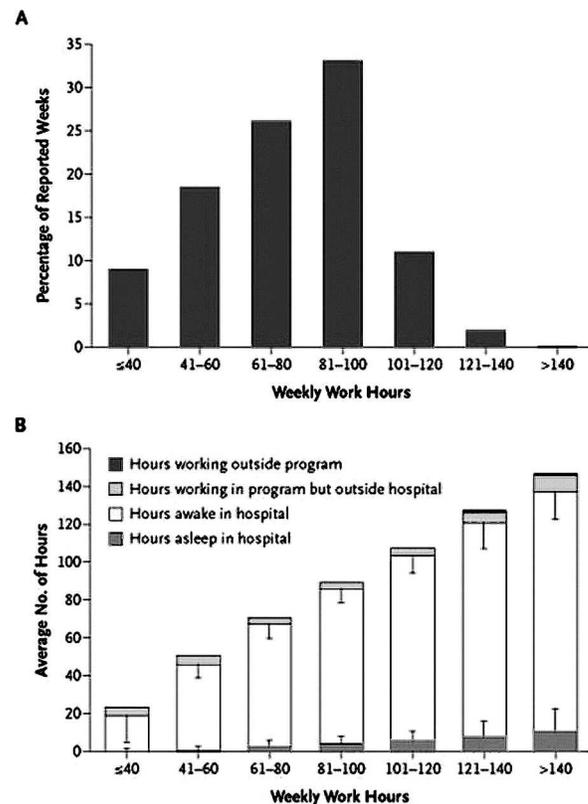


Fig 5A–B. Resident work hours and activity distribution. (A) The distribution of weekly work hours in 2,737 PGY-1 residents nationwide in 2002–2003 is shown. Residents worked more than 80 hours per week 40% of the time, including more than 10% with 100+ hours per week. (B) The proportion of hours spent awake and asleep in the hospital are relatively stable regardless of the number of hours worked per week; the vast majority of the reported hours were spent awake in the hospital, even when residents worked 120 hours or more. The very long work hours presumably reflect near-continuous call or the practice of ‘power weekends’ (> 48 hours continuous work) in order to obtain time off later. Reproduced with permission from LK Barger, BE Cade, NT Ayas, JW Cronin, B Rosner, FE Speizer, CA Czeisler. Extended work shifts and the risk of motor vehicle crashes among interns. *New Engl J Med.* 2005; 352:125–134. © 2005 Massachusetts Medical Society. All rights reserved.

additional 9.1% (3.4–14.7%) over baseline, and the risk of a crash on the commute from work by 16.2% (7.8–24.7%). This means that residents working for a month on a traditional ‘‘Q3’’ schedule with 10 extended duration work shifts > 24 hours had a 162% increased risk of a crash on the commute from work in that month. Volunteers also reported a 2–3-fold increase in the likelihood of falling asleep while driving or while stopped in traffic, as the increasing number of extended duration shifts worked each month increased, as compared to months without extended shifts.⁹

traditional shifts. While working on the intervention schedule, residents also slept more ($p < 0.001$) on average (7.4 ± 0.9 hours/day), compared to when they worked on the traditional schedule (6.6 ± 0.8 hours/day) and exhibited less ($p < 0.02$) than half the rate of attentional failures while on duty overnight (0.33/hour versus 0.69/hour). During the intervention schedule, subjects were also encouraged to take a nap before beginning their 'night-call' (Fig 6) and they did so on 70% of occasions. There was a reciprocal relationship ($r = -0.57$) between sleep and work hours, such that residents had ~20 minutes more sleep per week for each hour that their work week was reduced ($p < 0.001$) (Fig 7). The distribution of sleep relative to work hours was also altered ($p < 0.001$) with a smaller proportion of work hours performed with less than 4 hours sleep in the preceding 24 hours on the intervention as compared to the traditional schedule (Fig 8).

During the traditional schedule, PGY-1 residents made 35.9% more ($p < 0.001$) serious medical errors than when they worked the intervention schedule (136.0 versus 100.1/1000 patient days). They made 27.8% more inter-

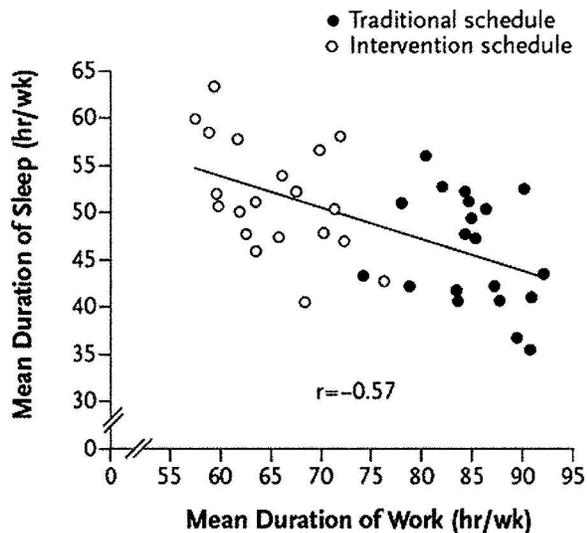


Fig 7. Relationship between weekly work and sleep hours. Seventeen out of 20 residents slept more on the intervention schedule as compared to the traditional one although all residents worked fewer hours on the intervention. As seen above, a reciprocal relationship was observed when average weekly sleep and work hours were correlated for the traditional and intervention schedules combined. The regression analysis predicted an increase of 19.2 minutes sleep per week for each single work hour reduction. Reproduced with permission from SW Lockley, JW Cronin, EE Evans, BE Cade, CJ Lee, CP Landrigan, JM Rothschild, JT Katz, CM Lilly, PH Stone, D Aeschbach, CA Czeisler. Effect of reducing interns' weekly work hours on sleep and attentional failures. *New Engl J Med.* 2004;351:1829-1837. © 2004 Massachusetts Medical Society. All rights reserved.

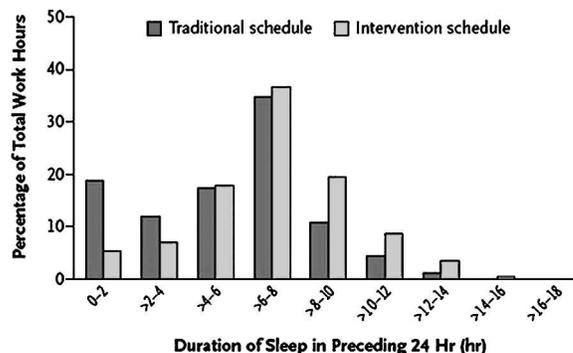


Fig 8. Distribution of sleep in relation to duty hours. Figure 8 shows the distribution in the amount of sleep in the 24 hours prior to each work hour for the traditional and intervention schedules. A greater proportion of work hours were preceded by more sleep during the intervention compared to the traditional schedule represented by the relative shift to the right of the distribution for the intervention schedule. A smaller proportion of work hours were preceded by 4 hours of sleep or less during the intervention (13%) compared to the traditional schedule (31%), and a greater proportion of work hours followed 8 hours of more sleep in the prior 24 hours (33% versus 11%, respectively). Reproduced with permission from SW Lockley, JW Cronin, EE Evans, BE Cade, CJ Lee, CP Landrigan, JM Rothschild, JT Katz, CM Lilly, PH Stone, D Aeschbach, CA Czeisler. Effect of reducing interns' weekly work hours on sleep and attentional failures. *New Engl J Med.* 2004; 351:1829-1837. © 2004 Massachusetts Medical Society. All rights reserved.

cepted serious errors on the traditional as compared to the intervention schedule (70.3 versus 55.0/1000 patient days, $p = 0.02$), and 56.6% non-intercepted serious errors (44.8 versus 28.6/1000 patient days, $p < 0.001$). The increased number of PGY-1 errors on the traditional schedule led to more ($p < 0.001$) errors overall on the units during the traditional schedule as compared to the intervention, with 22.0% (193.2 versus 158.4) more serious medical errors overall. When categorized according to type of error, PGY-1 residents made 20.8% more serious medication errors ($p = 0.03$) and 5.6-fold more serious diagnostic errors ($p < 0.001$) when working on the traditional schedule, rates that were also reflected unit-wide (17.1% increase in medication errors ($p = 0.03$) and 96.4% more diagnostic errors ($p < 0.001$).⁵¹

DISCUSSION

Collectively, the findings to date from the Harvard Work Hours Health and Safety Group strongly demonstrate the risk to both residents and patients of continuing to permit extended duration work shifts of 24 hours or more. When working extended duration shifts, residents are at a higher

risk of lapses of vigilance and committing serious medical errors, and are more than twice as likely to crash their cars while driving home than when they do not work these shifts. Restricting residents to 16 hours of scheduled continuous duty increases sleep duration outside work, improves attentiveness on duty overnight, and reduces the rate of medical errors. The improvements observed in the intervention study were found despite the addition of a fourth resident to the team and an increase in the number of hand-offs between physicians, as also observed elsewhere,⁵⁵ suggesting that the perceived risk of changing continuity of care is less than the risk of error due to sleep deprivation. There was also no evidence in our study that more senior staff undertook an increased burden of care as a result of reduction in junior residents' hours, as has been suggested,^{15,48,86} as there were no differences in the total number of medication orders or tests interpreted by PGY-1 residents between the schedules, and the PGY-1s performed significantly more procedures per patient-day ($p < 0.001$) during the intervention schedule than when they worked the traditional one.

In considering the design of new work schedules, it is important to keep in mind the biological principles underlying fatigue: fundamentally, all sleep hours and all wake hours are not equal. A simple reduction in work hours may achieve an administrative goal but may not optimize the time at which sleep opportunities are available. Poorly designed schedules that reduce work may inadvertently reduce sleep and increase fatigue, and subsequently increase the risk of medical errors and crashes. While the focus is often on weekly work hour limits and the permissible frequency of extended duration work shifts, eliminating these extended duration shifts outright is likely to have a much greater impact of resident health and patient safety than attempting to achieve an arbitrary work-hour limit of 80 hours per week.⁵⁰ We purposely designed our intervention with these principles in mind. Key considerations included avoiding consecutive night-calls in order to minimize chronic sleep deprivation; allowing nearly 24 hours off after night-calls to enable sufficient recovery from acute sleep deprivation; reducing night-call duration to minimize sleeping on-shift and thereby reduce the risk of sleep inertia; allowing time for a long recovery sleep after the day-call to reduce chronic sleep deprivation; and, notably, enabling and encouraging residents to take a nap before coming onto night-call, thereby interrupting the build-up of homeostatic sleep pressure before they come onto a shift and blunting the severity of the circadian performance nadir overnight. An additional consideration that was not optimal in this study, however, was the effort to formalize the sign-out process, particularly during the evening sign-out. There was a great deal of variability in how each team managed the content and quality of the sign-out

and, subsequently, those residents who were called upon to present at rounds were not always fully aware of the patients' history. We feel that developing a system of formal rounds in the afternoon or evening, supervised by senior residents or the attending physician,³ would greatly improve the communication within the team and the perception that continuity of care was adequate, as well as providing more frequent educational opportunities for the residents. The potential for error inherent in this suboptimal hand-off, however, was insufficient to negate the significant improvement in serious error rates gained by the elimination of extended duration work shifts.

Another important consideration in planning resident schedules is the fact that residents, as a result of their sense of professionalism, will often want to work longer than scheduled.⁵² Although in our intervention study the maximum scheduled shift duration was 16 hours, 40% of the shifts actually lasted between 16–20 hours.⁵³ Assuming that this level of resident professionalism holds true across specialties and systems, it may be preferable to schedule residents to work less than the maximum number of hours legally allowed, as many will undoubtedly work longer than scheduled; we therefore suggest that scheduled work hours be less than the proscribed limits.

The introduction of 'night-floats' has been a common strategy to reduce the work hours of on-call residents,^{48,52,54} despite the increase in hand-offs, lack of continuity when residents are brought in from other services, and the perceived reduction in educational opportunities for the resident being covered. Although we observed a slight increase in the amount of sleep obtained by those residents who had night float coverage compared to those without it in the survey (36 minutes per shift), this approach is unlikely to be a robust solution to address work hour limits. Previously, we measured the amount of sleep obtained in residents on-call with and without four hours of night-float coverage⁷² and found that those with coverage did not sleep significantly more than those without coverage, as residents were reportedly using their protected time for sleep to catch up on paperwork and other tasks.⁷² Our current data suggest that spending more hours at the hospital does not allow a greater proportion of time to sleep (Fig 5).⁹ A reduction in the absolute number of work hours, however, can be an effective way to increase sleep duration if the schedule is designed to facilitate sleep. In our intervention study, about one-third of all time made available by reduced work hours was used for sleep,⁵³ contrary to others' expectations,⁶² but in line with typical sleep-wake behavior (Fig 7).

Following the introduction of the ACGME guidelines, there have been many editorials and surveys purportedly addressing the impact of the regulations on medical and surgical residency programs^{19,30,38,40,43,46–48,54,88}

and many have reported a negative response.^{11,15,29,36,52,56,64,80,84,86} It is difficult to interpret subjective reports that lack validated measures of work hours, sleep and fatigue, especially given that the 2003 regulations did little to change the practices of many residency programs where work weeks longer than 80 hours and extended duration work shifts are still reportedly common.^{52,55,84} Although the ACGME has reported a high rate of compliance with the duty hour standards,² several preliminary studies have suggested that true rates of compliance may be substantially lower.^{5,16,69} Lack of compliance with the ACGME regulations may underlie the failure of several studies to detect any impact of work hour regulations on clinical performance,^{7,58,61,66} especially as reductions in work hours or changes in fatigue were not objectively confirmed. It may also call into question the appropriateness of the ACGME being both the body to which programs report, and which provides program accreditation. Further multi-center studies of true rates of ACGME compliance across specialties are needed.

The reduction of work hours has raised legitimate concerns regarding continuity of patient care, reduced educational opportunities, and the tradition of professionalism.^{29,56,78} What is lacking, however, are objective data addressing solutions to these concerns. The vast majority of recent reports consist of opinion or surveys of residents or program directors, but remarkably few contain experimental data collected using rigorous study designs or validated instruments for measuring medical error rates or quality of care. While opinion surveys provide interesting points of debate, they are not sufficient to address the issues regarding resident work hour reduction. Subjective data may be particularly hazardous when quantifying sleepiness given the disconnect between actual performance and subjective ratings when chronically sleep deprived (Fig 4).⁷⁷ The guiding operational principle in this endeavor should be that outcome-based evidence must direct policy towards development of the best practice. Researchers need to conduct well-designed trials that provide objective data from which evidence-based decisions can be made regarding how best to reform resident work hours while guarding against the risks to patient care and resident education outlined above. Residency programs routinely make evidence-based decisions in clinical practice and even in selecting trainees^{2,3} but have appeared reluctant to rely on such data to develop safe resident work hour schedules that are optimal for both training and patient care. The challenge to the medical and surgical professions is to replace conjecture with evidence and take a proactive role in finding workable solutions to eliminate extended shifts. Several progressive institutions have taken up this challenge and successfully adopted work hour reductions across their residency programs, instituting maximum

shifts of 12 to 14 hours,^{3,14,42} or employing physicians' assistants to redistribute some of the workload,⁵⁶ which suggests that the required changes can be achieved. Moreover, it should be noted that, while US programs struggle to achieve 80-hour work weeks, European countries are implementing 56-hour work week limits. Although the European solution remains a work in progress,⁵⁷ it suggests that substantially greater reductions in consecutive and total weekly work hours are possible to achieve in high quality health care systems.

At the 2005 ABJS/AOA Carl T. Brighton Workshop on Orthopaedic Education, an attendee likened the ACGME work hour guidelines to reducing the speed limit from 55 mph to 35 mph—an initiative that would no doubt make the roads safer but may be considered excessive and impractical (Dempsey S. Springfield, MD, 12 Nov 2005, oral communication). Given the fact that the legal work limits in other high risk industries in the United States are set between 8 and 12 consecutive hours,^{27,28} a more appropriate analogy may be that the current regulations reduce the residents' speed limit from 150 mph to 100 mph, still allowing them to travel twice as fast as others are legally permitted. This situation is unsafe and while extended duration work shifts persist, they will continue to place both residents' and patients' health and safety at risk.

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