Published in final edited form as:

Sleep Health. 2016 December ; 2(4): 309–315. doi:10.1016/j.sleh.2016.08.003.

Impact of extended duty hours on medical trainees

Pnina Weiss, MD^{a,*}, Meir Kryger, MD^b, and Melissa Knauert, MD, PhD^b

^aSection of Pediatric Respiratory Medicine and Medical Education, Yale University School of Medicine, 333 Cedar St, PO Box 208064, New Haven, CT 06520-8064

^bSection of Pulmonary, Critical Care and Sleep Medicine, Department of Medicine, Yale University School of Medicine, 333 Cedar St, PO Box 208057, New Haven, CT 06520-8057

Abstract

Many studies on resident physicians have demonstrated that extended work hours are associated with a negative impact on well-being, education, and patient care. However, the relationship between the work schedule and the degree of impairment remains unclear. In recent years, because of concerns for patient safety, national minimum standards for duty hours have been instituted (2003) and revised (2011). These changes were based on studies of the effects of sleep deprivation on human performance and specifically on the effect of extended shifts on resident performance. These requirements necessitated significant restructuring of resident schedules. Concerns were raised that these changes have impaired continuity of care, resident education and supervision, and patient safety. We review the studies on the effect of extended work hours on resident well-being, education, and patient care as well as those assessing the effect of work hour restrictions. Although many studies support the adverse effects of extended shifts, there are some conflicting results due to factors such as heterogeneity of protocols, schedules, subjects, and environments. Assessment of the effect of work hour restrictions has been even more difficult. Recent data demonstrating that work hour limitations have not been associated with improvement in patient outcomes or resident education and well-being have been interpreted as support for lifting restrictions in some specialties. However, these studies have significant limitations and should be interpreted with caution. Until future research clarifies duty hours that optimize patient outcomes, resident education, and well-being, it is recommended that current regulations be followed.

Keywords

Resident; Fatigue; Duty hour; Sleep deprivation; Accreditation Council for Graduate Medical Education; Medical education; Medical trainees

Background

Until 2003, the on-duty hours of residents traditionally averaged more than 80 h/wk, with a significant number reporting more than 110 h/wk, particularly during their internship.¹

*Corresponding author. pnina.weiss@yale.edu (P. Weiss).

Disclosure

The authors have no conflict of interest.

Traditional in-house call included extended shifts of more than 36 hours every 2 to 3 days. Extended on-duty shifts are associated with both acute and chronic sleep deprivation and sleep fragmentation.^{2–4} Studies demonstrating that sleep deprivation adversely affected trainees emerged in the 1970s. One-third of residents reported that their long duty hours impaired their ability to work with adequate efficiency.^{5,6} In addition, extended work shifts adversely impacted the quality of care^{6,7} and interactions with patients^{6,7} and staff,¹ and resulted in significant medical errors.^{1,5} Many subsequent studies have demonstrated that extended work hours negatively impact resident well-being, education, and patient care. However, there are others that show no adverse effect. Potential reasons for the discrepancy will be explored in this review.

Over the last 30 years, there has been a dramatic change in the structure of medical training, precipitated by concerns for patient safety in the face of extended shifts and resident fatigue. Challenges to the tradition of extended shifts for residents were raised in 1984 after the death of Libby Zion, an 18-year-old college student who died within 24 hours of admission in a New York hospital. She was under the care of an intern and second-year resident, carrying a high volume of patients, who were supervised via telephone by an attending physician. The cause of her death was likely an uncommon, but fatal interaction between her antidepressant and a sedative she was administered. However, in addition to a lack of adequate supervision, the culpability of resident fatigue due to extended duty hours was raised.⁸ Although formal investigations did not provide convincing evidence that extended work hours or resident fatigue played a role in her death, it became the catalyst for work hour reform. As a result of the Libby Zion case, the Bell Commission was formed to evaluate the training and supervision of doctors in the state. In 1989, based on the recommendations of the committee, New York State limited duty hours to 80 hours a week (averaged for 4 weeks); however, no other states followed suit.

In 1999, the landmark Institute of Medicine (IOM) *To Err is Human: Building a Safer Health System* raised grave concerns over the integrity of patient safety in hospitals.⁹ Concerns about the relationship between sleep deprivation and reduced performance led to legislative proposals to limit resident work hours. Finally in 2003, the Accreditation Council for Graduate Medical Education (ACGME) instituted national minimum standards which included limits to an 80-hour week (averaged for 4 weeks) and 24 hours of continuous duty with additional 6 hours for transfer of care and educational activities (Table 1).¹⁰ The requirements necessitated significant restructuring of resident schedules. Duty periods were broken down into more shifts of shorter duration, often using a night float system. The frequency of overnight calls for residents was decreased. Protected sleep periods were sometimes instituted. Overnight call in some specialties was transitioned to home call. Other modifications included increasing the number of residents, hiring ancillary staff and health professionals, shifting work to attending physicians, and restructuring the educational curriculum. These restrictions were further adjusted in 2011 to make specific recommendations based on postgraduate year and to address implementation of night float systems.

The effects of the duty-hour restrictions on resident well-being, education, and patient safety have been examined in a number of studies and systematic reviews, and the results are

conflicting. However, to measure the effect of the work hour restrictions, it is critical to first have an understanding of the effect of extended hours on these parameters. We review herein the known effects of extended work hours and resultant sleep deprivation on resident well-being, education, and patient safety and then the impact of the duty-hour restrictions. MEDLINE and PubMed databases were searched for peer-reviewed, English-language research studies, review articles, and meta-analyses on sleep loss in resident physicians, published between 1971 and 2016, using combinations of the Medical Subject Heading sleep deprivation, internship and residency, housestaff, intern, resident, or physicians in training and by examining reference lists of retrieved articles.

The effect of traditional extended shifts on residents

Resident well-being

Sleepiness—Extended work hours and decreased sleep are associated with sleepiness; this is reflected in higher scores on Epworth Sleepiness Scale,¹¹ Stanford Sleepiness Scale,^{12–14} and visual analog scale.¹⁴ Sleep latency on multiple sleep latency test was decreased in anesthesiology residents both during their traditional rotation (5 overnight calls/mo) and immediately after 24-hour call (6.7 ± 5.3 and 4.9 ± 4.7 minutes, respectively), reflecting the effects of both chronic and acute sleep deprivation.² In contrast, when they were able to sleep for 4 nights, the sleep latency normalized in almost all of them (12.0 ± 6.4 minutes); only 1 of the 11 participants remained hypersomnolent under all conditions. In another study, sleepiness and mood changes did not resolve after the first recovery night period in internal medicine residents, again potentially reflecting the effects of chronic sleep deprivation.³

Importantly, residents underreported their degree of sleepiness, which may reflect an impairment in their ability to perceive it accurately. Despite higher scores on sleepiness scales with extended work hours, surgical residents scored lower on a sleep deprivation impact scale when compared with nonsurgical residents who worked fewer hours and were less sleepy.¹⁵ In another study, anesthesiology residents demonstrated poor ability to discriminate microsleeps documented by electroencephalogram. They failed to report sleep in 49% of the episodes identified by electroencephalogram as sleep and when they reported that they had stayed awake, they were wrong 76% of the time.²

Mood—Studies demonstrating that sleep deprivation adversely affected the mood of medical trainees emerged in the 1970s. In 1971, Friedman et al¹⁶ reported that sleep-deprived internal medicine interns (with a mean of 1.8 hours of sleep) reported increased sadness, decreased vigor, egotism, and social affection. Difficulty thinking, depression, irritability, depersonalization, inappropriate affect, and memory deficit were reported by interns.¹⁷ In 1981, Small¹⁸ described the “house officer stress syndrome” characterized by episodic cognitive impairment, chronic anger, pervasive cynicism, and family discord, as being prevalent in a “benign form” in most house officers, caused by sleep deprivation and excessive workload. Severely affected house officers suffered from major depression, suicidal ideation, and substance abuse. Sleep deprivation was associated with higher stress levels in residents, which was worse in those with large patient loads, inadequate support

from attending physicians, less robust social support systems, inadequate time to pursue personal matters, and competition from peers.¹⁹

Many subsequent studies demonstrated that residents developed mood impairment during their training. Increased anger, tension, confusion, depression, and fatigue were reported in surgical residents, most pronounced in interns.²⁰ Sleep loss and fragmentation in medical residents intensified negative emotions and fatigue after daytime disruptive events.²¹ Sleep loss and fatigue adversely impacted learning and cognition; job performance, including professionalism and task performance; and personal life, including personal well-being and relationships with spouse or significant other and family.²²

Similarly, sleep deprivation and extended shifts have been associated with resident burnout.²³ In orthopedic residents, sleep deprivation was associated with high levels of burnout, increased emotional exhaustion, depersonalization, and psychological stress and a decreased sense of personal achievement and marital satisfaction.²³ However, the relationship between burnout and extended work hours is not always clear; in medical residents, reduced sleep duration was not associated with burnout.²⁴ However, it is possible that the sleep data may have been gathered during low-intensity work periods.

Cognitive impairment—Sleep deprivation adversely affects cognitive function in many studies; extended shifts and sleep deprivation in residents have been associated with impairment in attention and psychomotor vigilance,^{12,14,25–28} working memory,^{26,28–30} cognitive processing,²⁷ balance,³¹ fine motor skills,³² verbal and numeric skills,^{30,33} visuomotor performance,^{30,33} and response inhibition.²⁸ Studies have included surgical, medical, pediatric, anesthesiology, and obstetrical residents. Medical residents on a rotation with every third overnight call (24–30 hours) demonstrated impairment in their attention (measured by psychomotor vigilance testing) both acutely after an extended shift and over the course of 3-week rotation.⁴ As seen in the studies of sleepiness, sleep deprived individuals poorly perceived the extent of their cognitive impairment. In a study by Qureshi et al,³⁴ after a 24-hour call, pediatric residents had impairment in verbal recall and logic memory, concentration, reaction time, vigilance, and hand-eye coordination and attention lapses. However, the residents did not report any deterioration in their performance.

In contrast, other studies have demonstrated that extended shifts had no effect on cognitive testing. In a study by Bartle et al,³⁵ post-call surgical residents (with less than 2 hours of sleep) demonstrated no impairment in attention and psychomotor vigilance, working memory, problem solving, visuomotor performance, motor tasks, or verbal skills when compared with a “rested” state (mean, 6.5 hours of sleep), despite reporting more mood disturbances (eg, fatigue, depressive symptoms, tension confusion, and anger). Similarly, Deaconson et al³⁶ reported that post-call surgical residents who were sleep deprived (defined by a lack of 4 hours of continuous sleep) did not demonstrate impairment in the same domains of cognitive testing.

Resident safety—Extended shifts have been associated with risks to resident safety, specifically exposure to blood-borne pathogens and motor vehicle accidents (MVAs). Blood-borne pathogen exposure is uncommon; in one study, the daytime rate was 40 accidents per

hour per 1000 doctors in training.³⁷ However, the exposure rate was 50% higher during the night shift.³⁷ The increased risk of percutaneous injuries during the night shift was confirmed in the study of Ayas et al³⁸; the risk was also higher when working an extended shift (>24 hours).

Many studies demonstrate that extended shifts are associated with a higher risk of MVAs and near-miss MVAs in residents. Marcus and Loughlin³⁹ reported that of 70 pediatric residents (on overnight call every fourth night), 44% had fallen asleep when stopped at a light and 23% had fallen asleep while driving. A total of 49% had fallen asleep at the wheel; 90% of these events occurred post-call. The residents were involved in 20 MVAs. In a survey of 1554 emergency medicine residents, 8% reported having MVAs and 58% reported being involved in near-miss MVAs. Most of the MVAs and near-miss MVAs followed the night shift. The risk of MVAs and near-miss MVAs increased with the number of night shifts worked per month and were inversely related to residents' tolerance to shiftwork.⁴⁰ In a survey of 2737 interns, the odds ratios for reporting a MVA and for reporting a near-miss MVA after an extended work shift (average 32 hours), as compared with a shorter shift, were 2.3 and 5.9, respectively. Every extended work shift that was scheduled in a month increased the monthly risk of a MVA by 9.1% and increased the monthly risk of a MVA during the commute from work by 16.2%. In months in which interns worked five or more extended shifts, the risk that they would fall asleep while driving or while stopped in traffic was significantly increased.⁴¹ More recent studies describe similar results. In internal medicine residents, 11%–15% reported MVA and 43% near-miss MVA.^{11,42} An increased risk of motor vehicle incident was associated with decreased quality of life, burnout, depression, fatigue, and sleepiness.⁴²

In simulated driving, post-call residents demonstrated impaired performance. In some medical residents, there was impairment in reaction time, resistance to monotony, anticipation speed, and visual-motor coordination.⁴³ In another study, impairment, as measured by lane variance, crash frequency, was more pronounced in men than in women.⁴⁴ In addition, post-call pediatric residents demonstrated a decrease in attention and vigilance similar to blood alcohol level of 0.04%–0.05%.¹⁴

Education

The effect of extended shifts on resident education has been assessed by their impact on a number of parameters such as actual and simulated clinical performance, clinical knowledge, patient volumes, conference attendance, and satisfaction. The results have been conflicting.

Extended hours have been associated with impairment in resident clinical performance in some studies. Studies have shown associations between sleep deprivation and errors in electrocardiogram interpretation¹⁶ and impairment in detecting significant changes in monitored variables (such as blood pressure, heart rate, and gas flow rate) using simulated videos⁴⁵ and managing a simulated critically ill patient.⁴⁶ Decrements in the performance of sleep-deprived surgical residents have also been demonstrated. When monitored by videotaping during actual procedures, sleep-deprived residents (<2 hours' sleep) had inferior performance and operative inefficiency marked with indecision and poorly planned

maneuvers.⁴⁷ Using simulated laparoscopic procedures, post-call surgical residents made more errors and were less efficient than rested residents.^{48,49} In contrast, in other studies, extended duty hours did not seem to decrease resident simulated or clinical performance. Obstetrical residents (who slept for <2 hours) had no deterioration in their skills of placing an epidural during labor regardless of level of training.⁵⁰ Post-call residents (24 hours) demonstrated no impairment in their performance in structured clinical interviews with actors posing as patients,⁵¹ laboratory form testing,⁵² or simulated suturing technique.⁵² A study by Storer et al⁵³ assessed the effect of 24 vs 36 hours of sleep deprivation on cognitive and procedural skills of pediatric residents; there was no deterioration in cognitive skills (written knowledge examination), endotracheal intubation, or vein catheterization associated with the longer shift. However, umbilical artery catheterization took longer.

The effect of sleep deprivation on clinical knowledge recall is also mixed. Jacques et al⁵⁴ showed a decline in test scores on the in-training exam with decreasing sleep on the night before the examination in family practice residents. Loss of one night's sleep resulted in changes in test scores that were approximately equivalent in magnitude to the change that occurred in test scores between residents in the first and third year of training. The adverse impact of sleep deprivation on training exam scores was also demonstrated in surgical residents.⁵⁵ However, in the study by Reznick and Folse,⁵² extended shifts had no effect on the performance of surgical residents on a knowledge test. Likewise, in the study by Browne et al,⁵⁶ there was no decrease in short- or long-term memory or learning as reflected in scores on knowledge tests based on journal articles either 1 week or 3 months after being on call.

Patient care

The potential for extended duty hours to have an adverse impact on patient care has raised much concern. Surveys of interns found that they reported more medical errors, preventable fatigue-related adverse events (including those leading to fatalities), and attentional failures during extended shift rotations.⁵⁷ However, studies have not consistently demonstrated that resident extended duty hours are associated with worsening patient outcomes. A study of 6371 surgical cases showed no statistically significant increase in complication incidence when the resident operated after 24-hour call.⁵⁸ Morbidity, mortality, and complication rates were not increased when surgical procedures were performed overnight by residents when compared with those done during the day.^{59–61}

ACGME work hour restrictions

Concerns about the relationship between sleep deprivation and impaired performance in medical trainees led to the ACGME work hour restrictions in 2003 (Table 1). However, adherence to the requirements raised a number of concerns: (1) the increase in transitions of care would contribute to more errors in communication and adversely impact patient safety; (2) resident education would suffer because of interruptions in continuity of care, fewer educational opportunities (particularly on night shift), and a decrease in patient volume and procedures; (3) “shift mentality” would be fostered, which would adversely impact professionalism and leave residents poorly prepared for the long hours required by the

profession; (4) the educational environment including supervision of residents and faculty oversight over transitions of care, improving handovers was not addressed in the new ACGME requirements; (5) the “one size fits all” model did not account for differences between subspecialties in education and patient care; (6) changes would be prohibitively expensive; and (7) there was no mechanism in place to measure the impact of the changes on patient safety or resident education.

In 2008, the IOM produced a report *Resident Duty Hours: Enhancing Sleep, Supervision, and Safety*⁶² and examined evidence on resident fatigue and patient safety. The committee implicated sleep loss, inexperience, workload intensity, inadequate supervision, poor handover practices, and systems issues as factors contributing to resident errors, but acknowledged that the relative importance of each factor was unclear. The report recommended further duty-hour revisions (Table 1), fatigue prevention and mitigation strategies, greater supervision, adjustment of residents’ workload, and improvement in patient transfers. It also stressed a stronger culture of safety and enhanced teamwork in patient care. In 2011, the ACGME revised the requirements again (Table 1), adopting some of the IOM’s recommendations. Specifically, the new requirements limited interns to 16 hours/shift. Strategic napping was strongly suggested, and programs were required to teach residents alertness management. In addition, stronger requirements were put into place to ensure increased supervision, adjustment of residents’ workload, and oversight of patient transfers.

Effect of the 2003 ACGME work hour restrictions

Studies of the effect of limiting extended shifts on resident well-being have been conflicting. Early systematic reviews indicated some improvement in resident quality of life.^{63,64} Studies have demonstrated improvements in sleep duration,⁶⁵ sleepiness,^{66–68} stress,⁶⁶ burnout,⁶⁹ satisfaction,^{66,70} quality of life,⁶⁹ motivation,⁶⁹ morale,⁶⁸ time for independent reading,⁶⁷ availability for family events,⁶⁷ relationships with staff,⁶⁷ and depression.⁷¹ A prospective randomized controlled study on resident sleepiness compared internal medicine residents in an intensive care unit on traditional call (maximum shift 30 hours) with those with maximum 16 hour shifts. They demonstrated that the latter slept more (5.8 h/wk) and had half the attentional failures at night.⁷² However, other studies demonstrated no improvement in satisfaction,⁷⁰ and mood,⁷¹ or increased duration of sleep with shorter duration shifts.⁷³ However, many of these studies are limited by the fact that data were based on self-reports, which are subject to bias.

The impact of limiting extended shifts on resident education was measured in a number of studies. In some studies, in-training examination scores improved.^{68,74} In contrast, no change in performance on end of rotation examination,⁷⁵ in training examination,^{76,77} operative case volumes,^{74,76–79} or conference participation⁸⁰ were demonstrated in other studies. There did not appear to be a consistent impact in systematic reviews.^{63,64}

The effect of duty-hour restrictions on patient care was assessed in a number of studies. In a randomized control trial, interns made substantially more serious medical errors when they worked frequent extended shifts than when they worked shorter shifts (30 hours vs 16 hours).⁸¹ These included significantly more serious medication errors and 5.6 times as many

serious diagnostic errors. However, there was no difference in adverse events.⁸¹ In some studies, the work hour restrictions were associated with a decrease in the length of stay,^{80–82,91,95} medication errors,^{82,83} and 6-month mortality,⁸⁴ and an improvement in adherence to evidenced-based guidelines,⁸⁴ patient discharge rate,⁸³ physician efficiency,⁶⁷ resident-nursing communication,⁶⁷ and Press Ganey satisfaction surveys.⁶⁷ However, other investigations demonstrated no difference in patient length of stay,⁷⁵ 30-day readmission rate,⁸³ mortality,^{69,75,77,83,84} adverse drug interactions,⁸³ complication rates,^{69,77} or medical errors.⁶⁶

Recent studies

More recent studies, incorporating the 2009 IOM recommendations or the 2011 ACGME requirement revisions, assessed specific interventions such as shift length, night float, and protected sleep time on resident well-being, education, and patient care. However, they have been no more conclusive than the earlier studies. A recent systematic review concluded that the duty-hour restrictions did not improve resident well-being or patient care and appeared to have a negative effect on resident education.⁸⁵ However, not all modifications in schedule were equivalent. Reduced shift length was associated with modest improvement in patient care as demonstrated by shorter length of stay^{86,87} and decreased surgical complication rate.⁶⁰ However, other studies showed no effect on either,^{61,88} or on mortality,^{60,87,88} readmission rates,^{87,88} intensive care unit transfers,⁸⁸ patient safety indicators,⁸⁸ or continuity of care.⁸⁷ Reduced shift length had mixed results on resident well-being,^{89–91} and a negative impact on education as measured by quantity and quality of patient encounters,⁹¹ operative volume,⁹² and lecture attendance.⁹³ In the one randomized controlled study comparing 12- vs 30-hour shifts, residents on the shorter shift reported a decrease in overall well-being as reflected in work-life balance, job satisfaction, burnout, and motivation and in the quality of education.⁹¹ An increase in work load intensity may have played a role.

A large national cluster-randomized study on the effect of duty-hour flexibility (FIRST) was recently completed.⁹⁴ In this study by Bilimoria et al, surgical residency programs were randomly assigned to current ACGME “standard” duty hours or “flexible” policies that waived rules on the maximum shift lengths and time off between shifts for residents, potentially resulting in longer shifts. There was no difference in 30-day rate of postoperative death or serious complications, other postoperative complications, or resident satisfaction with their well-being or education. Those in the flexible duty-hour group were less likely to be dissatisfied with continuity of care and transitions in care. However, they were more likely to be dissatisfied with time for rest and to perceive that duty hours had a negative impact on time on rest, health, and time with family and friends and extracurricular activities. Interestingly, there was no significant difference between the groups on how often they reported that fatigue affected personal or patient safety. The authors concluded that less restrictive, extended shift policies were noninferior to standard ACGME duty-hour policies and that “it may be reasonable to have specialty-specific duty-hour requirements.” A similar national study of flexible shifts in internal medicine residency programs is presently underway.⁹⁵

Many studies on night float demonstrated unfavorable outcomes on resident well-being as measured by cognitive testing,^{96,97} and fatigue and sleepiness⁹⁶ with mixed results on total sleep time^{96,98} when compared with traditional call. Most studies found a negative impact on resident education.^{85,98,99} The effect on patient care parameters was mixed^{98,100} with no change on length of stay, mortality, and readmission rates.¹⁰⁰ In the one randomized control trial comparing night float (6 consecutive nights) to traditional extended call every fourth night, night float decreased intern attendance at teaching conferences, patient volumes, continuity of care, and perceived quality of patient care.⁹⁸ In one study, melatonin was unsuccessful in improving the fatigue, sleep, or overall attention of residents on a night float rotation.¹⁰¹ Of note, almost all the studies used a night float duration of at least 5 nights, which is longer than the 4-day duration recommended by the IOM.

There are few studies on the effect of protected sleep time on residents. In a randomized controlled study, instituting a 5-hour nap from 12:30 AM to 5:30 AM during an extended shift resulted in increased amount of sleep, decreased sleepiness, and improved vigilance and attention on psychomotor testing.¹⁰² In another study, a 20-minute midday nap improved subsequent attention and cognitive testing.¹⁰³

Limitations of the studies

The inconsistency in results on the effect of extended hours on resident sleepiness and performance are not surprising given the heterogeneity of protocols, schedules, subjects, and environments. The effects of sleep deprivation are modulated by a number of factors including sleep history, circadian rhythms, level of arousal, test, and individual characteristics.¹⁰⁴ The duration of extended shifts (acute sleep deprivation) varied between studies and they did not control for prior sleep amount and distribution. Chronic sleep deprivation was most likely a factor in influencing the response to acute sleep deprivation; it may worsen the effect of acute sleep deprivation or it may mask the effect of further decrement from short-term sleep loss. The influence of circadian rhythm on test performance is well known,¹⁰⁴ and the time of testing was often not specified or varied both within and between many of the studies. There was no control for arousing influences including activity, bright light, noise, temperature, previous drug use (caffeine, stimulants), and motivation. Different cognitive tests were used, which have variable sensitivity in detecting the effects of sleep deprivation. Even for one type of test (ie, psychomotor vigilance test), the duration and testing conditions varied between studies. Individual characteristics such as sex and vulnerability to the effects of sleep deprivation are important. Many of the studies that demonstrated a lack of effect of extended shifts on performance were performed in surgical residents who may have chosen their profession based on their ability to tolerate sleep deprivation. In addition, participant selection was not controlled, and residents who were most vulnerable to the effects of sleep loss may have selectively refused to participate in these studies. Another significant limitation is the use of self-report instruments (ie, residents' perception of the quality of education or their satisfaction with the program), which are subject to bias and have issues with both validity and reliability. Finally, the effect of impaired resident performance on patient outcomes is difficult to measure. In some cases, the outcome such as mortality may be a rare event. In addition, patient outcomes are a reflection of a multitude of factors such as patient characteristics (ie, severity of

illness), task factors (ie, educational value and caseload), team factors, work and learning environment, and organizational and management factors (ie, workflow and efficient informational systems). The effect of any one factor such as resident fatigue is very difficult to tease out from the others.

Given the difficulties in consistently documenting an effect of extended shifts on residents, it is not surprising that the studies on the effect of work hour restriction are variable. Interventions often included changes in schedule, not just shorter work hours; the studies compared traditional overnight call with shifts of shorter duration (16 hours), less frequent overnight call, and/or night float and did not always measure work or sleep hours. Many studies had methodological limitations including small sample sizes, short follow-up, and the use of opinion surveys and self-reports, which are subjective and subject to bias. Few were randomized and none were blinded. In addition, many of the studies used a pre-post design which is subject to time series bias. Observed results could have been due to many factors including modifications in treatment protocols, curriculum, or supervision.

The recent large national cluster-randomized study on the effect of duty-hour flexibility in surgical training programs by Bilimoria et al⁹⁴ is a particularly important contribution, given the dearth of large randomized controlled studies. The authors demonstrated that a policy of flexible duty hours (which eliminated the recent limits on maximum duration of duty period for interns and residents and minimum time off between scheduled duty periods) was not associated with an increased rate of postoperative death or serious complications or resident dissatisfaction with overall education quality or well-being when compared with a standard policy which adhered to the present ACGME restrictions. However, the study did have limitations. It was designed as a pragmatic, noninferiority trial. The study used resident self-reports to assess the effect of extended hours on resident dissatisfaction and educational quality which are subject to bias. The differences between the duty-hour requirements for the 2 groups appear to be modest, and the lack of differences in key features of the schedule may contribute to the lack of significant differences between groups (eg, both groups were permitted to work up to 80 hours per week). No data were collected regarding actual on-call schedules or duty-hour logs. Differences between groups may be further masked because there was some variability in adherence to some of the extended duty periods in the flexible policy group. No data were collected regarding sleep (ie, sleep duration or quality), which may limit the interpretations that can be drawn. In addition, it is difficult to assess the role of one particular factor such as resident fatigue or work schedule on patient outcomes, because they are the result of an interplay of many factors such as supervision, team factors, environment, and organizational and management factors. For example, it is possible that other team members (ie, anesthesiologists and senior nurses), patient safety factors (eg, use of surgical checklist) and staffing, and institutional and cultural changes resulting from the 2003 and 2011 hour restrictions may have mitigated any impairments in surgical resident performance. The study did not evaluate for changes in handoff protocols or supervision. Nor did it examine the effect of duty-hour policy on MVAs, blood-borne pathogen exposure, medication errors or other resident-sensitive outcomes, or objective measures of educational performance such as in-training examination scores or cognitive testing.

Conclusion

There is good evidence to suggest that extended work hours are associated with adverse effects on resident well-being, education, and patient care. However, because of limitations in experimental design, it is difficult to assess the effect of the 2003 and 2011 ACGME-mandated work hour restrictions. The recent national study by Bilimoria et al⁹⁴ has been raised as justification for eliminating some of the restrictions on maximum shift length and minimum time off between shifts, at least in surgical training programs. However, there are many limitations to the study. Data on the impact of sleep deprivation on human and resident performance should provide caution to liberalizing duty-hour restrictions. The study does, at least, provide reassurance that the increase in transitions of care has not been associated with a deterioration in patient outcomes. It is clear that better outcome measures and standardized interventions are needed. More data are needed to determine the optimal way to design rotations (night call of 4 days vs night float) and the curricular or system modifications that are necessary to improve them. Residents and faculty need to be educated about the importance of adequate sleep, because residents frequently do not use opportunities to nap strategically or obtain recovery sleep when off duty. Efforts should be made to improve supervision and transitions of care, which, in conjunction with work hour limitation, should improve patient safety. The effect of work hour limits on residents' preparation for practice is an area that deserves more scrutiny, for it may require increasing the duration of training, which could potentially burden the already overstrained graduate medical education budget. It is critical to better understand the relationship between resident schedules and sleep deprivation to develop strategies to optimize work schedules to improve resident well-being, education, and patient safety.

References

1. 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(11):1154–1163. [PubMed: 14604880]
2. Howard SK, Gaba DM, Rosekind MR, Zarcone VP. The risks and implications of excessive daytime sleepiness in resident physicians. *Acad Med.* 2002; 77(10):1019–1025. [PubMed: 12377678]
3. Rose M, Manser T, Ware JC. Effects of call on sleep and mood in internal medicine residents. *Behav Sleep Med.* 2008; 6(2):75–88. [PubMed: 18443947]
4. Anderson C, Sullivan JP, Flynn-Evans EE, Cade BE, Czeisler CA, Lockley SW. Deterioration of neurobehavioral performance in resident physicians during repeated exposure to extended duration work shifts. *Sleep.* 2012; 35(8):1137–1146. [PubMed: 22851809]
5. Wilkinson RT, Tyler PD, Vary CA. Duty hours of young hospital doctors: effects on the quality of work. *J Occup Psychol.* 1975; 48(4):219–229.
6. McManus IC, Lockwood DN, Cruickshank JK. The preregistration year: chaos by consensus. *Langmuir.* 1977; 1(8008):413–417.
7. Lewittes LR, Marshall VW. Fatigue and concerns about quality of care among Ontario interns and residents. *CMAJ.* 1989; 140(1):21–24. [PubMed: 2909268]
8. Lerner, BA. The Washington Post. Nov 28, 2006 Case that Shook Medicine.
9. To Err Is Human: Building a Safer Health System. Washington, DC: Institute of Medicine; 2000.
10. ACGME (Accreditation Council for Graduate Medical Education). Common Program Requirements for Duty Hours. Chicago, IL: 2003.
11. Pikovsky O, Oron M, Shiyovich A, Perry ZH, Nesher L. The impact of sleep deprivation on sleepiness, risk factors and professional performance in medical residents. *Isr Med Assoc J.* 2013; 15(12):739–744. [PubMed: 24449976]

12. Saxena AD, George CF. Sleep and motor performance in on-call internal medicine residents. *Sleep*. 2005; 28(11):1386–1391. [PubMed: 16335328]
13. Wali SO, Qutah K, Abushanab L, Basamh R, Abushanab J, Krayem A. Effect of on-call-related sleep deprivation on physicians' mood and alertness. *Ann Thorac Med*. 2013; 8(1):22–27. [PubMed: 23439930]
14. Arnedt JT, Owens J, Crouch M, Stahl J, Carskadon MA. Neurobehavioral performance of residents after heavy night call vs after alcohol ingestion. *JAMA*. 2005; 294(9):1025–1033. [PubMed: 16145022]
15. Woodrow SI, Park J, Murray BJ, Wang C, Bernstein M, Reznick RK, et al. Differences in the perceived impact of sleep deprivation among surgical and non-surgical residents. *Med Educ*. 2008; 42(5):459–467. [PubMed: 18412885]
16. Friedman RC, Bigger JT, Kornfeld DS. The intern and sleep loss. *N Engl J Med*. 1971; 285(4):201–203. [PubMed: 5087723]
17. Friedman RC, Kornfeld DS, Bigger TJ. Psychological problems associated with sleep deprivation in interns. *J Med Educ*. 1973; 48(5):436–441. [PubMed: 4699420]
18. Small GW. House officer stress syndrome. *Psychopharmacology*. 1981; 22(10):860–869.
19. Ford CV, Wentz DK. Internship: what is stressful? *South Med J*. 1986; 79(5):595–599. [PubMed: 3704727]
20. Light AI, Sun JH, McCool C, Thompson L, Heaton S, Bartle EJ. The effects of acute sleep deprivation on level of resident training. *Curr Surg*. 1989; 46(1):29–30. [PubMed: 2721234]
21. Zohar D, Tzischinsky O, Epstein R, Lavie P. The effects of sleep loss on medical residents' emotional reactions to work events: a cognitive-energy model. *Sleep*. 2005; 28(1):47–54. [PubMed: 15700720]
22. Papp KK, Stoller EP, Sage P, Aikens JE, Owens J, Avidan A, et al. The effects of sleep loss and fatigue on resident-physicians: a multi-institutional, mixed-method study. *Acad Med*. 2004; 79(5):394–406. [PubMed: 15107278]
23. Sargent MC, Sotile W, Sotile MO, Rubash H, Barrack RL. Quality of life during orthopaedic training and academic practice. Part 1: orthopaedic surgery residents and faculty. *J Bone Joint Surg Am*. 2009; 91(10):2395–2405. [PubMed: 19797575]
24. Thomas NK. Resident burnout. *JAMA*. 2004; 292(23):2880–2889. [PubMed: 15598920]
25. Sharp KH, Vaughn GM, Cosby PW, Sewell CE, Kennaway DJ. Alterations of temperature, sleepiness, mood, and performance in residents are not associated with changes in sulfatoxymelatonin excretion. *J Pineal Res*. 1988; 5(6):499–512. [PubMed: 3225734]
26. Hart RP, Buchsbaum DG, Wade JB, Hamer RM, Kwentus JA. Effect of sleep deprivation on first-year residents' response times, memory, and mood. *J Med Educ*. 1987; 62(11):940–942. [PubMed: 3681926]
27. Orton DI, Gruzelier JH. Adverse changes in mood and cognitive performance of house officers after night duty. *BMJ*. 1989; 298(6665):21–23. [PubMed: 2492842]
28. Lingenfelser T, Kaschel R, Weber A, Zaiser-Kaschel H, Jakober B, Kuper J. Young hospital doctors after night duty: their task-specific cognitive status and emotional condition. *Med Educ*. 1994; 28(6):566–572. [PubMed: 7862021]
29. 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(2):167–170. [PubMed: 14739384]
30. Hawkins MR, Vichick DA, Silsby HD, Kruzich DJ, Butler R. Sleep and nutritional deprivation and performance of house officers. *J Med Educ*. 1985; 60(7):530–535. [PubMed: 4009667]
31. Cuthbertson DW, Bershad EM, Sangi-Hagheykar H, Cohen HS. Balance as a measurement of fatigue in postcall residents. *Laryngoscope*. 2015; 125(2):337–341. [PubMed: 24933004]
32. Ayalon RD, Friedman F Jr. The effect of sleep deprivation on fine motor coordination in obstetrics and gynecology residents. *Am J Obstet Gynecol*. 2008; 199(5):576 e571–575. [PubMed: 18822404]
33. Narang V, Laycock JR. Psychomotor testing of on-call anaesthetists. *Anaesthesia*. 1986; 41(8):868–869. [PubMed: 3752472]

34. Qureshi AU, Ali AS, Hafeez A, Ahmad TM. The effect of consecutive extended duty hours on the cognitive and behavioural performance of paediatric medicine residents. *J Pak Med Assoc.* 2010; 60(8):644–649. [PubMed: 20726195]
35. Bartle EJ, Sun JH, Thompson L, Light AI, McCool C, Heaton S. The effects of acute sleep deprivation during residency training. *Surgery.* 1988; 104(2):311–316. [PubMed: 3400062]
36. Deaconson TF, O'Hair DP, Levy MF, Lee MB, Schueneman AL, Codon RE. Sleep deprivation and resident performance. *JAMA.* 1988; 260(12):1721–1727. [PubMed: 3411755]
37. Parks DK, Yetman RJ, McNeese MC, Burau K, Smolensky MH. Day-night pattern in accidental exposures to blood-borne pathogens among medical students and residents. *Chronobiol Int.* 2000; 17(1):61–70. [PubMed: 10672434]
38. Ayas NT, Barger LK, Cade BE, Hashimoto DM, Rosner B, Cronin JW, et al. Extended work duration and the risk of self-reported percutaneous injuries in interns. *JAMA.* 2006; 296(9):1055–1062. [PubMed: 16954484]
39. Marcus CL, Loughlin GM. Effect of sleep deprivation on driving safety in housestaff. *Sleep.* 1996; 19(10):763–766. [PubMed: 9085483]
40. Steele MT, Ma OJ, Watson WA, Thomas HA Jr, Muelleman RL. The occupational risk of motor vehicle collisions for emergency medicine residents. *Acad Emerg Med.* 1999; 6(10):1050–1053. [PubMed: 10530665]
41. Barger LK, Cade BE, Ayas NT, Cronin JW, Rosner B, Czeisler CA, et al. Extended work shifts and the risk of motor vehicle crashes among interns. *N Engl J Med.* 2005; 352(2):125–134. [PubMed: 15647575]
42. West CP, Tan AD, Shanafelt TD. Association of resident fatigue and distress with occupational blood and body fluid exposures and motor vehicle incidents. *Mayo Clin Proc.* 2012; 87(12):1138–1144. [PubMed: 23218084]
43. Tornero C, Ventura A, Bourguet M, Poquet I. Evaluation of driving ability among residents after the duty shift. *Accid Anal Prev.* 2012; 47:182–183. [PubMed: 22405248]
44. Ware JC, Risser MR, Manser T, Karlson KH Jr. Medical resident driving simulator performance following a night on call. *Behav Sleep Med.* 2006; 4(1):1–12. [PubMed: 16390281]
45. Denisco RA, Drummond JN, Gravenstein JS. The effect of fatigue on the performance of a simulated anesthetic monitoring task. *J Clin Monit.* 1987; 3(1):22–24. [PubMed: 3819792]
46. Sharpe R, Koval V, Ronco JJ, Qayumi K, Dodek P, Wong H, et al. The impact of prolonged continuous wakefulness on resident clinical performance in the intensive care unit: a patient simulator study. *Crit Care Med.* 2010; 38(3):766–770. [PubMed: 20068462]
47. Goldman LI, McDonough MT, Rosemond GP. Stresses affecting surgical performance and learning. I. Correlation of heart rate, electrocardiogram, and operation simultaneously recorded on videotapes. *J Surg Res.* 1972; 12(2):83–86. [PubMed: 5062414]
48. Taffinder NJ, McManus IC, Gul Y, Russell RC, Darzi A. Effect of sleep deprivation on surgeons' dexterity on laparoscopy simulator. *Langmuir.* 1998; 352(9135):1191.
49. Grantcharov TP, Bardram L, Funch-Jensen P, Rosenberg J. Laparoscopic performance after one night on call in a surgical department: prospective study. *BMJ.* 2001; 323(7323):1222–1223. [PubMed: 11719413]
50. Hayter MA, Friedman Z, Katznelson R, Hanlon JG, Borges B, Naik VN. Effect of sleep deprivation on labour epidural catheter placement. *Br J Anaesth.* 2010; 104(5):619–627. [PubMed: 20354007]
51. Engel W, Seime R, Powell V, D'Alessandri R. Clinical performance of interns after being on call. *South Med J.* 1987; 80(6):761–763. [PubMed: 3589767]
52. Reznick RK, Folse JR. Effect of sleep deprivation on the performance of surgical residents. *Am J Surg.* 1987; 154(5):520–525. [PubMed: 3674301]
53. Storer JS, Floyd HH, Gill WL, Giusti CW, Ginsberg H. Effects of sleep deprivation on cognitive ability and skills of pediatrics residents. *Acad Med.* 1989; 64(1):29–32. [PubMed: 2914061]
54. Jacques CH, Lynch JC, Samkoff JS. The effects of sleep loss on cognitive performance of resident physicians. *J Fam Pract.* 1990; 30(2):223–229. [PubMed: 2299318]
55. Godellas CV, Huang R. Factors affecting performance on the American Board of Surgery in-training examination. *Am J Surg.* 2001; 181(4):294–296. [PubMed: 11438261]

56. Browne BJ, Van Susteren T, Onsager DR, Simpson D, Salaymeh B, Condon RE. Influence of sleep deprivation on learning among surgical house staff and medical students. *Surgery*. 1994; 115(5): 604–610. [PubMed: 8178259]
57. Barger LK, Ayas NT, Cade BE, Cronin JW, Rosner B, Speizer FE, et al. Impact of extended-duration shifts on medical errors, adverse events, and attentional failures. *PLoS Med*. 2006; 3(12):e487. [PubMed: 17194188]
58. Haynes DF, Schwedler M, Dyslin DC, Rice JC, Kerstein MD. Are postoperative complications related to resident sleep deprivation? *South Med J*. 1995; 88(3):283–289. [PubMed: 7886523]
59. Ellman PI, Kron IL, Alvis JS, Tache-Leon C, Maxey TS, Reece TB, et al. Acute sleep deprivation in the thoracic surgical resident does not affect operative outcomes. *Ann Thorac Surg*. 2005; 80(1): 60–65. [PubMed: 15975341]
60. Yaghoubian A, Kaji AH, Putnam B, de Virgilio C. Trauma surgery performed by “sleep deprived” residents: are outcomes affected? *J Surg Educ*. 2010; 67(6):449–451. [PubMed: 21156307]
61. Yaghoubian A, Kaji AH, Ishaque B, Park J, Rosing DK, Lee S, et al. Acute care surgery performed by sleep deprived residents: are outcomes affected? *J Surg Res*. 2010; 163(2):192–196. [PubMed: 20655546]
62. Ulmer, C., Wolman, DM., Johns, M. Resident Duty Hours: Enhancing Sleep, Supervision and Safety; Committee on Optimizing Graduate Medical Trainee (Resident) Hours and Work Schedules to Improve Patient Safety. Washington, DC: Institute of Medicine; National Academies Press; 2009.
63. Levine AC, Adusumilli J, Landrigan CP. Effects of reducing or eliminating resident work shifts over 16 hours: a systematic review. *Sleep*. 2010; 33(8):1043–1053. [PubMed: 20815185]
64. Fletcher KE, Underwood W III, Davis SQ, Mangrulkar RS, McMahon LF Jr, Saint S. Effects of work hour reduction on residents’ lives: a systematic review. *JAMA*. 2005; 294(9):1088–1100. [PubMed: 16145030]
65. Philibert I, Nasca T, Brigham T, Shapiro J. Duty-hour limits and patient care and resident outcomes: can high-quality studies offer insight into complex relationships? *Annu Rev Med*. 2013; 64:467–483. [PubMed: 23121182]
66. Sawyer RG, Tribble CG, Newberg DS, Pruett TL, Minasi JS. Intern call schedules and their relationship to sleep, operating room participation, stress, and satisfaction. *Surgery*. 1999; 126(2): 337–342. [PubMed: 10455903]
67. Goldstein MJ, Kim E, Widmann WD, Hardy MA. A 360 degrees evaluation of a night-float system for general surgery: a response to mandated work-hours reduction. *Curr Surg*. 2004; 61(5):445–451. [PubMed: 15475093]
68. Carey JC, Fishburne JIA. Method to limit working hours and reduce sleep deprivation in an obstetrics and gynecology residency program. *Obstet Gynecol*. 1989; 74(4):668–672. [PubMed: 2797646]
69. Hutter MM, Kellogg KC, Ferguson CM, Abbott WM, Warshaw AL. The impact of the 80-hour resident workweek on surgical residents and attending surgeons. *Ann Surg*. 2006; 243(6):864–871. discussion 871–865. [PubMed: 16772790]
70. Lund KJ, Teal SB, Alvero R. Resident job satisfaction: one year of duty hours. *Am J Obstet Gynecol*. 2005; 193(5):1823–1826. [PubMed: 16260242]
71. Gottlieb DJ, Peterson CA, Parenti CM, Lofgren RP. Effects of a night float system on housestaff neuropsychologic function. *J Gen Intern Med*. 1993; 8(3):146–148. [PubMed: 8455112]
72. Lockley SW, Cronin JW, Evans EE, Cade BE, Lee CJ, Landrigan CP, et al. Effect of reducing interns’ weekly work hours on sleep and attentional failures. *N Engl J Med*. 2004; 351(18):1829–1837. [PubMed: 15509816]
73. 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(2):217–223. [PubMed: 15124713]
74. 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(4):531–538. [PubMed: 12375759]

75. Afessa B, Kennedy CC, Klarich KW, Aksamit TR, Kolars JC, Hubmayr RD. Introduction of a 14-hour work shift model for housestaff in the medical ICU. *Chest*. 2005; 128(6):3910–3915. [PubMed: 16354863]
76. Kelly A, Marks F, Westhoff C, Rosen M. The effect of the New York State restrictions on resident work hours. *Obstet Gynecol*. 1991; 78(3 Pt 1):468–473. [PubMed: 1876386]
77. de Virgilio C, Yaghoubian A, Lewis RJ, Stabile BE, Putnam BA. The 80-hour resident workweek does not adversely affect patient outcomes or resident education. *Curr Surg*. 2006; 63(6):435–439. discussion 440. [PubMed: 17084773]
78. Ferguson CM, Kellogg KC, Hutter MM, Warshaw AL. Effect of work-hour reforms on operative case volume of surgical residents. *Curr Surg*. 2005; 62(5):535–538. [PubMed: 16125616]
79. McElearney ST, Saalwachter AR, Hedrick TL, Pruett TL, Sanfey HA, Sawyer RG. Effect of the 80-hour work week on cases performed by general surgery residents. *Am Surg*. 2005; 71(7):552–555. discussion 555–556. [PubMed: 16089117]
80. Welling RE, Boberg JT, Weinberg E, Gulley J. Work hours compliance in a community hospital. *Curr Surg*. 2004; 61(2):241–243. [PubMed: 15051273]
81. Landrigan CP, Rothschild JM, Cronin JW, Kaushal R, Burdick E, Katz JT, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004; 351(18):1838–1848. [PubMed: 15509817]
82. Gottlieb DJ, Parenti CM, Peterson CA, Lofgren RP. Effect of a change in house staff work schedule on resource utilization and patient care. *Arch Intern Med*. 1991; 151(10):2065–2070. [PubMed: 1929696]
83. Horwitz LI, Kosiborod M, Lin Z, Krumholz HM. Changes in outcomes for internal medicine inpatients after work-hour regulations. *Ann Intern Med*. 2007; 147(2):97–103. [PubMed: 17548401]
84. Bhavsar J, Montgomery D, Li J, Kline-Rogers E, Saab F, Motivala A, et al. Impact of duty hours restrictions on quality of care and clinical outcomes. *Am J Med*. 2007; 120(11):968–974. [PubMed: 17976424]
85. Bolster L, Rourke L. The effect of restricting residents' duty hours on patient safety, resident well-being, and resident education: an updated systematic review. *J Grad Med Educ*. 2015; 7(3):349–363. [PubMed: 26457139]
86. Rosenbluth G, Fiore DM, Maselli JH, Vittinghoff E, Wilson SD, Auerbach AD. Association between adaptations to ACGME duty hour requirements, length of stay, and costs. *Sleep*. 2013; 36(2):245–248. [PubMed: 23372272]
87. Emlet LL, Al-Khafaji A, Kim YH, Venkataraman R, Rogers PL, Angus DC. Trial of shift scheduling with standardized sign-out to improve continuity of care in intensive care units. *Crit Care Med*. 2012; 40(12):3129–3134. [PubMed: 23034459]
88. Choma NN, Vasilevskis EE, Sponsler KC, Hathaway J, Kripalani S. Effect of the ACGME 16-hour rule on efficiency and quality of care: duty hours 2.0. *JAMA Intern Med*. 2013; 173(9):819–821. [PubMed: 23545839]
89. Sen S, Kranzler HR, Didwania AK, Schwartz AC, Amarnath S, Kolars JC, et al. Effects of the 2011 duty hour reforms on interns and their patients: a prospective longitudinal cohort study. *JAMA Intern Med*. 2013; 173(8):657–662. discussion 663. [PubMed: 23529201]
90. Wysocki AP, McGowan B. Revising the surgical registrar on-call roster. *ANZ J Surg*. 2010; 80(7–8):490–494. [PubMed: 20795960]
91. Auger KA, Landrigan CP, Gonzalez del Rey JA, Sieplinga KR, Sucharew HJ, Simmons JM. Better rested, but more stressed? Evidence of the effects of resident work hour restrictions. *Acad Pediatr*. 2012; 12(4):335–343. [PubMed: 22626586]
92. Schwartz SI, Galante J, Kaji A, Dolich M, Easter D, Melcher ML, et al. Effect of the 16-hour work limit on general surgery intern operative case volume: a multi-institutional study. *JAMA Surg*. 2013; 148(9):829–833. [PubMed: 23843028]
93. DeLaroche A, Riggs T, Maisels MJ. Impact of the new 16-hour duty period on pediatric interns' neonatal education. *Clin Pediatr (Phila)*. 2014; 53(1):51–59. [PubMed: 24002047]
94. Bilimoria KY, Chung JW, Hedges LV, Dahlke AR, Love R, Cohen ME, et al. National cluster-randomized trial of duty-hour flexibility in surgical training. *N Engl J Med*. 2016

95. Desai SV. Individualized Comparative Effectiveness of Models Optimizing Patient Safety and Resident Education (iCOMPARE). Webpage. clinicalTrials.gov. [accessed Oct 1, 2016] Last updated August 29, 2016.
96. Naughton PA, Aggarwal R, Wang TT, Van Herzeele I, Keeling AN, Darzi AW, et al. Skills training after night shift work enables acquisition of endovascular technical skills on a virtual reality simulator. *J Vasc Surg.* 2011; 53(3):858–866. [PubMed: 20952142]
97. Brandenberger J, Kahol K, Feinstein AJ, Ashby A, Smith M, Ferrara JJ. Effects of duty hours and time of day on surgery resident proficiency. *Am J Surg.* 2010; 200(6):814–818. discussion 818–819. [PubMed: 21146026]
98. Desai SV, Feldman L, Brown L, Dezube R, Yeh HC, Punjabi N, et al. Effect of the 2011 vs 2003 duty hour regulation-compliant models on sleep duration, trainee education, and continuity of patient care among internal medicine house staff: a randomized trial. *JAMA Intern Med.* 2013; 173(8):649–655. [PubMed: 23529771]
99. Luks AM, Smith CS, Robins L, Wipf JE. Resident perceptions of the educational value of night float rotations. *Teach Learn Med.* 2010; 22(3):196–201. [PubMed: 20563940]
100. McCoy CP, Halvorsen AJ, Loftus CG, McDonald FS, Oxentenko AS. Effect of 16-hour duty periods on patient care and resident education. *Mayo Clin Proc.* 2011; 86(3):192–196. [PubMed: 21307390]
101. Cavallo A, Ris MD, Succop P, Jaskiewicz J. Melatonin treatment of pediatric residents for adaptation to night shift work. *Ambul Pediatr.* 2005; 5(3):172–177. [PubMed: 15913411]
102. Volpp KG, Shea JA, Small DS, Basner M, Zhu J, Norton L, et al. Effect of a protected sleep period on hours slept during extended overnight in-hospital duty hours among medical interns: a randomized trial. *JAMA.* 2012; 308(21):2208–2217. [PubMed: 23212498]
103. Amin MM, Graber M, Ahmad K, Manta D, Hossain S, Belisova X, et al. The effects of a mid-day nap on the neurocognitive performance of first-year medical residents: a controlled interventional pilot study. *Acad Med.* 2012; 87(10):1428–1433. [PubMed: 22914520]
104. Alhola P, Polo-Kantola P. Sleep deprivation: impact on cognitive performance. *Neuropsychiatr Dis Treat.* 2007; 3(5):553–567. [PubMed: 19300585]

Table 1

Comparison of duty-hour limitations between the 2003 and 2011 ACGME requirements and the 2009 IOM Recommendations

	ACGME 2003 requirements	IOM 2009 recommendations	2011 ACGME requirements
Maximum h/wk	80 h, averaged for 4 wk	80 h, averaged for 4 wk	80 h, averaged for 4 wk
Maximum duration of duty period	30 h 24 h consecutive duty 6 h additional allowed No new patients after 24 h	30 h (5-h nap required after 16 h) 16 h without nap No new patients after 16 h	16 h for interns 28 h for more senior residents 24 h consecutive duty 4 h additional allowed Napping recommended No new patients after 24 h
In hospital on-call frequency	Every 3rd night, averaged for 4 wk	Every 3rd night, no averaging	Every 3rd night, averaged for 4 wk
Minimum time off between scheduled duty periods	10-h off between all daily duty periods and in-house call	10 h after regular daytime duty 12-h off after night duty 14-h off after extended duty period and must not return before 6 AM	Should have 10 h and must have 8 h between duty periods (exceptions for residents in final years) 14 h after in-house call
Minimum off-duty time	24 h off in 7 days, averaged for 4 wk	24 h off in 7 days, no averaging, plus golden weekend (48 h/month)	24-h off in 7 d, averaged for 4 wk
Maximum frequency of in-house night duty (night float)	As per subspecialty	4 consecutive nights and must have 48-h off	6 consecutive nights Max 4 wk/y; max 1 consecutive wk