Association of Workload of On-Call Medical Interns With On-Call Sleep Duration, Shift Duration, and Participation in Educational Activities

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Context Further restrictions in resident duty hours are being considered, and it is important to understand the association between workload, sleep loss, shift duration, and the educational time of on-call medical interns.

Objective To assess whether increased on-call intern workload, as measured by the number of new admissions on-call and the number of previously admitted patients remaining on the service, was associated with reductions in on-call sleep, increased total shift duration, and lower likelihood of participation in educational activities.

Design, Setting, and Participants Prospective cohort study of medical interns at a single US academic medical center from July 1, 2003, through June 24, 2005. Of the 81 interns, 56 participated (69%), for a total of 165 general medicine inpatient months resulting in 1100 call nights.

Main Outcome Measures On-call sleep duration, estimated by wrist watch actigraphy; total shift duration, measured from paging logs; and participation in educational activities (didactic lectures or bedside teaching), measured by experience sampling method via a personal digital assistant.

Results Mean (SD) sleep duration on-call was 2.8 (1.5) hours and mean (SD) shift duration was 29.9 (1.7) hours. Interns reported spending 11% of their time in educational activities. Early in the academic year (July to October), each new on-call admission was associated with less sleep (−10.5 minutes [95% confidence interval {CI}, −16.8 to −4.2 minutes]; P < .001) and a longer shift duration (13.2 minutes [95% CI, 3.2-23.3 minutes]; P = .01). A higher number of previously admitted patients remaining on the service was associated with a lower odds of participation in educational activities (odds ratio, 0.82 [95% CI, 0.70-0.96]; P = .01). Call nights during the week and early in the academic year were associated with the most sleep loss and longest shift durations.

Conclusion In this study population, increased on-call workload was associated with more sleep loss, longer shift duration, and a lower likelihood of participation in educational activities.

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See also p 1197.
tempt to address work intensification may result in residents doing the same amount of work in less time, which could undermine resident welfare and patient safety.14 Residents who are expected to work shorter hours but provide care for the same number of patients in a traditional extended shift may become so busy that they omit necessary patient care tasks, skip educational conferences, sleep less during their overnight shift, and leave beyond the shift limit. There may be an association between increased medical resident workload (defined by the number of patients admitted on the call day) and a higher risk of patient mortality.15 These relationships may be particularly important for internal medicine interns in a traditional extended-shift model, whose maximum on-call workload has remained constant at the ACGME cap of 5 new patient admissions within 24 hours.16

We therefore studied whether on-call workload of internal medicine interns was associated with on-call intern sleep, shift duration, and likelihood of participation in educational activities. We hypothesized that on-call workload, as measured by the numbers of patient admissions and remaining patients on the service, would be associated with less sleep, increased shift duration, and a lower likelihood of participation in educational activities.

METHODS

Study Design

Data for this study were collected from a cohort of internal medicine interns rotating on the University of Chicago inpatient general medicine service from July 1, 2003, through June 24, 2005. Interns served on the 1-month general medicine inpatient rotation 3 or 4 times per year. General medicine teams consisting of 1 attending physician, 1 resident, and 2 interns took overnight call, admitting new patients every fourth night.17 Interns were instructed to comply with the ACGME duty-hour restrictions. At the beginning of each rotation, interns were given instructions to leave the hospital 30 hours after starting their shift (either 1 PM or 2 PM of the postcall day depending on start time), depending on when they started their shift. During their 30-hour shift, interns were responsible for interviewing and examining newly admitted patients, creating admission histories, writing admission orders, following up on admission laboratory results, constructing a sign-out, and reporting interdepartmental updates to their supervising resident.

During the study period, on-call interns admitted new patients up to their ACGME maximum of 5 new patients within a 24-hour period. More than 90% of admitted patients presented to the emergency department. The supervising resident was responsible for evaluating whether a patient was appropriate for the floor and assigned patients to general medicine interns in alternating fashion. If a patient required admission to the intensive care unit, the attending physician was responsible for detecting sleep and estimating sleep duration.18,19 Interns were instructed to wear wristwatch actigraphs 24 hours per day for the duration of their general medicine month.20,21 Watch data were downloaded weekly at an intern conference into an actigraphy-based sleep scoring software program (Actiware software version 5.0, Mini-Mitter), which enables calculations of total sleep time in minutes (epoch length=1 minute; threshold medium).22 Intern call schedules were used to label sleep times that corresponded to overnight call periods.

From hospital paging logs, total shift duration was calculated as the difference in minutes between the time interns signed in their pager on the on-call day and the time interns signed out their pager (forwarded it to a covering physician) on the post-call day. To acknowledge the large number of shifts that ended shortly after 30 hours, a shift was deemed compliant if it ended before 30.5 hours.

Workload variables were constructed using data from the Hospitalist Project, a large ongoing study of patients hospitalized at the University of Chicago.23 Patient charts were abstracted for the names of the intern, resident, and attending physician caring for the patient and the admission day. After supervised review of 20 charts, research assistants abstracted data independently. To check data accuracy, abstracted data were compared with a master schedule of interns and their admitting days. Discrepancies occurred if interns switched call days, if an intern changed his/her name (eg, by marriage) during the year, or intern names were misspelled during abstraction. All discrepancies were rectified prior to
analysis. Using the call schedule and intern name, the numbers of patients admitted to each intern on his/her call day was calculated. In addition, the number of previously admitted patients remaining for each intern on his/her on-call day also was tabulated.

To assess the relationship between workload variables and intern education, data obtained in a time motion study of on-call intern activities were used with the experience sampling method24 between October 2003 and June 2004. On-call interns carried pocket PCs (Compaq iPAQ 3950, Palo Alto, California) that were programmed to provide a random alert in each 2-hour time window between 8 AM and midnight. Alerts from the pocket PCs prompted interns to report their current activity using a previously described scheme: direct patient care (eg, taking a history, performing a physical), indirect patient care (eg, charting, ordering tests, looking up laboratory results), education (didactic or bedside teaching), ancillary services (eg, phlebotomy, transportation), or personal activities (eg, eating, socializing).25 Responses were stored on a memory card that was downloaded at the end of each month. All interns received a 20-minute orientation on how to use the pocket PC experience sampling method and descriptions of the categories to code their activity.

Data Analysis

Descriptive statistics were used to summarize on-call sleep, workload variables (admissions on call day, remaining patients on call day), shift duration in minutes, and distribution of activities from the experience sampling method. Multivariate random-effects linear regression, controlling for clustering within intern and adjusting for time trends (period and day of week) and number of on-call extended shifts the intern had taken during the month rotation, was used to assess the relationship between workload variables (admissions on call day, remaining patients on call day) on on-call sleep estimated in minutes.

The academic year was grouped into 3 periods of 4 months each. Early ranged from July to October, middle from November to February, and late from March to June. To account for the differential effect of workload by period, interaction terms were constructed to correspond to workload due to additional admissions and remaining patients by academic period. Reference groups were Wednesday for day of week and early year (months of July to October) for period indicators and academic period, a linear combination of all effect of workload for each academic period, a linear combination of academic period coefficient and the academic period coefficient and the workload-period interactions. A similar model was used to ascertain the association between workload and shift duration in minutes. To obtain the overall effect of workload for each academic period, a linear combination of the academic period coefficient and the workload-period interaction coefficient was tested and reported. Multivariate random-effects logistic regression, adjusting for time trends and clustering within intern, was performed to ascertain the association between workload variables and likelihood of a compliant shift. Likelihood ratio tests and regression diagnostics were performed on the models to determine the correct covariance structure. 

In addition to random-effects analyses using observed only data, missing data were multiply imputed with 5 imputed values for each missing value.27 Missing on-call sleep (232 of 1100 observations missing [21%]) and shift duration data (150 of 1100 observations missing [14%]) were jointly imputed using a Bayesian multivariate normal imputation model in SAS version 9.1 (SAS Institute Inc, Cary, North Carolina).28 Because there were no meaningful differences between the observed and imputed analyses in terms of magnitude and significance of parameter estimates, the results from the random-effects analyses for sleep and shift duration are reported.

To account for polychotomous response for activity data from experience sampling method, a multinomial logistic regression model with random effects was fit using the SAS procedure PROC NLMIXED (SAS Institute Inc, Cary, North Carolina) to ascertain the association between workload variables and the relative odds of reporting participation in an activity (education, direct patient care, personal activity, or ancillary service) vs indirect patient care (most commonly reported activity) with statistical significance defined as P < .05.29

RESULTS

Of the 81 interns, 56 agreed to participate in the study (69%), for a total of 165 general medicine inpatient months resulting in 1100 call nights (TABLE 1).
During these call nights, interns provided care for 6457 patients (2732 new admissions), which represented 54% of all general medicine teaching inpatients under care on call days. Mean (SD) length of stay for patients during this period was 5.2 (7.4) days. Seventy-three percent of females (n=29) and 58% of males (n=27) participated in the study; there was no difference in sex between participants and nonparticipants (χ²=1.96; P=.16). There was no difference in age between participants and nonparticipants (mean [SD], 27.7 [2.3] years in participants vs 27.4 [1.6] years in nonparticipants; P=.61). Intern participation was higher in year 1 and early in the academic year (Table 1). Sleep data were obtained using wristwatch actigraphy for 868 of 1100 call nights (79%). Interns were less likely to wear the watch on Saturday nights (64% vs 84% on all other nights, P<.001), at the end of the academic year (71% vs 83% during other periods, P<.001), and in year 2 (72% vs 85% of nights during year 1, P<.001), resulting in fewer nights sampled during these periods. There were no significant differences in workload (admissions or remaining patients) between call nights for which sleep data were missing or present. Shift duration was available for 950 of 1100 nights (86%); availability did not correlate with academic period, day, or workload.

Admissions on-call per intern ranged from 0 to the intern cap of 5. Median number of new patients admitted on-call per intern was 3, with 29% admitting 2 patients and 30% admitting 3 patients. The median (interquartile range) number of patients per intern remaining from previous admissions on call nights was 3 (2-4). The median (interquartile range) total census per call night was 6 (4-7) patients. Mean (SD) sleep duration on-call was 2.8 (1.5) hours. Mean (SD) shift duration was 29.9 (1.7) hours. Approximately 30% of shifts were deemed noncompliant (>30.5 hours). There were more noncompliant shifts in the first year after duty-hour restrictions, but this was not statistically significant (35.5% vs 29% in year 2; P=.07).

Multivariate analysis demonstrated that each new on-call admission early in the academic year was associated with less sleep (−10.5 minutes [95% confidence interval {CI}, −16.8 to −4.2 minutes]; P<.001) (Table 2). The relationship between on-call admissions and on-call sleep was weaker later in the academic year, such that admissions late in the year were not associated with on-call sleep loss (−1.9 minutes [95% CI, −9.7 to 5.8]; P=.63). The number of patients remaining on the call day had no relationship to on-call sleep regardless of period. After controlling for workload, there were significant period and weekday associations with on-call sleep. Compared with early in the academic year, interns received substantially more on-call sleep as the academic year progressed (middle year, 30.3 minutes [95% CI, 17.4-43.2 minutes], P<.001; late year, 63.9 minutes [95% CI, 51.0-76.8 minutes], P<.001). After controlling for workload variables, weekend call nights (Saturday and Sunday) were characterized by substantially less sleep loss. For each subsequent on-call extended duty shift an intern had during the rotation, on-call sleep increased by approximately 4 minutes.

Using similar multivariate models, a significant association between admission workload and shift duration also

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**Table 2. Associations With On-Call Sleep and Shift Duration**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>On-Call Sleep (n = 868)</th>
<th>Shift Duration (n = 950)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β (95% CI), min</td>
<td>P Value</td>
</tr>
<tr>
<td><strong>Time per each additional on-call admission</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>−10.5 (−16.8 to −4.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Middle year</td>
<td>−7.3 (−14.8 to 0.09)</td>
<td>.05</td>
</tr>
<tr>
<td>Late year</td>
<td>−1.9 (−9.7 to 5.8)</td>
<td>.63</td>
</tr>
<tr>
<td><strong>Time per each previously admitted patient remaining on service</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>−4.5 (−9.4 to 0.4)</td>
<td>.07</td>
</tr>
<tr>
<td>Middle year</td>
<td>−2.4 (−8.2 to 3.5)</td>
<td>.43</td>
</tr>
<tr>
<td>Late year</td>
<td>5.8 (−0.4 to 11.9)</td>
<td>.07</td>
</tr>
<tr>
<td><strong>Period in academic year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>30.3 (17.4 to 43.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Middle year</td>
<td>63.9 (51.0 to 76.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Day of week</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monday</td>
<td>−5.9 (−22.8 to 11.1)</td>
<td>.50</td>
</tr>
<tr>
<td>Tuesday</td>
<td>−7.5 (−24.0 to 9.0)</td>
<td>.38</td>
</tr>
<tr>
<td>Wednesday</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>Thursday</td>
<td>−13.2 (−20.9 to 3.4)</td>
<td>.12</td>
</tr>
<tr>
<td>Friday</td>
<td>−1.3 (−18.8 to 16.1)</td>
<td>.88</td>
</tr>
<tr>
<td>Saturday</td>
<td>32.7 (13.7 to 51.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Sunday</td>
<td>30.6 (13.0 to 48.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Call shifts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time per each on-call shift that month</td>
<td>4.1 (1.7 to 6.6) &lt;.001</td>
<td>13.5 (−17.1 to −9.9) &lt;.001</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

aMultivariate random-effects regression model, controlling for intern participant, period in academic year, interactions between period in academic year and workload, day of the week, and number of on-call extended duty shifts an intern has taken during that general medicine month.

bMiddle-year and late-year coefficients are the difference in sleep or shift duration between early year at the median number of on-call admissions and remaining patients.

cIndicates the mean sleep and shift duration for an intern on call on a Wednesday early in the academic year who admits the median number of patients and has the median number of previously admitted patients remaining on the service.

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workload and Sleep duration for on-call medical interns

Table 3. Estimated On-Call Sleep and Shift Duration for a Hypothetical Intern With 3 Patients Remaining on Servicea

<table>
<thead>
<tr>
<th>No. of On-Call Admissions During Periodb</th>
<th>On-Call Sleep (95% CI), min</th>
<th>Shift Duration (95% CI), h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>173.1 (171.9-174.3)</td>
<td>29.48 (29.48-29.6)</td>
</tr>
<tr>
<td>Middle year</td>
<td>203.5 (202.2-204.7)</td>
<td>29.08 (29.08-29.2)</td>
</tr>
<tr>
<td>Late year</td>
<td>235.8 (234.4-237.2)</td>
<td>28.76 (28.7-28.8)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>162.6 (161.4-163.9)</td>
<td>29.74 (29.7-29.3)</td>
</tr>
<tr>
<td>Middle year</td>
<td>193.0 (191.7-194.3)</td>
<td>29.35 (29.3-29.4)</td>
</tr>
<tr>
<td>Late year</td>
<td>225.4 (224.0-226.8)</td>
<td>28.96 (28.9-29.0)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>152.2 (150.9-153.4)</td>
<td>29.96 (29.9-30.0)</td>
</tr>
<tr>
<td>Middle year</td>
<td>182.5 (181.3-183.8)</td>
<td>30.0 (29.5-29.6)</td>
</tr>
<tr>
<td>Late year</td>
<td>214.9 (213.5-216.3)</td>
<td>29.19 (29.15-29.24)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>141.7 (140.4-142.9)</td>
<td>30.2 (30.4-30.5)</td>
</tr>
<tr>
<td>Middle year</td>
<td>172.0 (170.8-173.3)</td>
<td>29.79 (29.7-29.8)</td>
</tr>
<tr>
<td>Late year</td>
<td>204.4 (203.0-205.8)</td>
<td>29.4 (29.37-29.5)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>131.2 (130.0-132.4)</td>
<td>30.4 (30.36-30.45)</td>
</tr>
<tr>
<td>Middle year</td>
<td>161.6 (160.3-162.8)</td>
<td>30.01 (29.96-30.05)</td>
</tr>
<tr>
<td>Late year</td>
<td>193.9 (192.5-195.3)</td>
<td>29.63 (29.6-29.7)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early year</td>
<td>120.7 (119.5-122.0)</td>
<td>30.62 (30.6-30.7)</td>
</tr>
<tr>
<td>Middle year</td>
<td>151.1 (149.8-152.3)</td>
<td>30.23 (30.2-30.3)</td>
</tr>
<tr>
<td>Late year</td>
<td>183.4 (182.0-184.8)</td>
<td>29.85 (29.8-29.9)</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

aSee footnote to Table 2 for details of model.
bPeriod in academic year is divided into early (July to October); middle (November to February); and late (March to June).

was observed. For each new on-call admission early in the academic year, shift duration increased by 13.2 minutes (95% CI, 3.2-23.3 minutes [P = .01]; Table 2). There was no association between the number of admissions and shift duration in the middle of the academic year, but late in the academic year on-call admissions were again associated with increased shift duration (15.5 minutes [95% CI, 4.5-26.6 minutes]; P = .006). In comparison, number of patients remaining was significantly associated with shift duration only in the middle of the academic year (13.3 minutes [95% CI, 4.3-22.3 minutes]; P = .004).

After controlling for workload, shift duration was shorter as the academic year progressed (compared with early year: middle year, −23.0 minutes [95% CI, −43.2 to −2.8 minutes], P = .03; late year, −45.8 minutes [95% CI, −65.5 to −26.2 minutes], P < .001). A significant weekday effect was observed, with the shortest shifts occurring on Friday and Saturday call nights. Shift duration decreased by approximately 13 minutes for each additional call night that an intern took in a particular month rotation.

For a hypothetical intern with the median of 3 remaining patients on the call day, on-call sleep would be just over 2 hours and shift duration would be the longest (30.6 hours) if an intern admitted 5 new admissions early in the academic year (Table 3). In contrast, the same workload late in the academic year would be associated with approximately 3 hours of on-call sleep and a shift duration of 29.9 hours. The odds of a compliant shift increased as the academic year progressed (compared with early year: middle year, OR, 1.71 [95% CI, 1.06-2.75], P = .03; late year, OR, 1.97 [95% CI, 1.27-3.07], P = .003).

From October 2003 to June 2004, 23 interns participated in the experience sampling method on 283 call days yielding 1044 observations, which represented 49% of intern time windows possible. Responses were equally distributed throughout the day. Response rates did not significantly vary by intern, month, or day. Education (defined as didactic lectures or bedside teaching) accounted for 11% of activities that interns reported, with 90% of all education responses occurring before 4 PM on the call day. The most common activity reported was indirect patient care (41%). Interns also reported spending time in the following activities: direct patient care (30%), personal activities (12%), and ancillary services (6%). In multivariate analysis, there was no relationship between on-call admissions and the relative distribution of activities reported. However, for each remaining patient on their service (admitted prior to the call day), interns had lower odds of reporting that they were engaged in educational activities (OR, 0.82 [95% CI, 0.70-0.96]; P = .01) or personal activities (OR, 0.77 [95% CI, 0.66-0.89]; P < .001) compared with indirect patient care.

**COMMENT**

To our knowledge, this is the first study to examine the relationship between intern workload, sleep, and shift duration using objective quantitative measures. Our findings suggest that early in the academic year in a traditional extended-duty shift model, each new admission on-call is associated with a reduction in the amount of on-call sleep and increase in total shift duration. An increase in the number of remaining patients on the census was associated with lower relative odds of reporting participation in educational activities and longer shift durations in the winter. Call nights during the week and early in the
academic year were associated with the most sleep loss and longest shift durations.
These findings raise concerns about the possibility of future duty-hour restrictions in the absence of corresponding limits on workload. Program directors may seek systems that optimize available house staff hours and resources to maximize coverage of inpatient care while maintaining compliance with duty hours.30 Yet, little attention has been given to the optimal workload for a given set of hours worked.31 Our study highlights the importance of considering reductions in on-call admissions as a strategy to alleviate sleep deprivation and ensure compliance with duty hours for interns early in the academic year in a traditional extended-duty shift model. In addition, lowering the number of remaining patients on the census may free time to participate in formal educational activities, especially those that occur in the morning and early afternoon (morning report, noon lecture), when interns are likely providing care for their remaining patients. The large fraction of indirect patient care reported suggests a need to reduce administrative work associated with patient care. These approaches are consistent with recent recommendations from the Association of Program Directors for Internal Medicine to reduce intern admission and census caps and eliminate administrative tasks, such as scheduling tests and appointments, to improve the learning environment.19 Given the continued reliance on residents for patient care in academic teaching hospitals, implementing these recommendations will likely require additional resources to redistribute work formerly done by residents to nonresident clinicians.

In evaluating optimal workload and resident schedules, it is equally important to consider intern experience, day of the week, and seasonal effects. After controlling for workload, shift durations were shortest for Friday and Saturday call nights, which corresponds to interns leaving the hospital early on Saturday and Sunday morning due to closure of routine hospital operations. In addition, Saturday and Sunday call nights were associated with less sleep loss, which could be due to patients admitted earlier in the day or held over from the previous night due to weekend admission patterns. Interns slept less and had longer shift durations at the beginning of internship. Shift durations in the middle of the academic year were not associated with on-call admissions, but instead with the number of patients remaining on the census on the call day; although there is no clear explanation, it is possible that interns in this period, which corresponds to winter months, are responsible for sicker patients that require more attention beyond the admission day. Together, these findings suggest the importance of additional staffing and resources during weekdays and early in the academic year, when interns are least efficient and most at risk of sleep loss. Some programs are considering graduated caps or limits that incrementally increase as interns progress through the academic year (Paul Aronowitz, MD, APDIM list-serv, May 18, 2008).

This study, albeit from a single institution, may inform a larger ongoing discussion about the best schedule for residents to admit and provide care for patients within duty-hour restrictions. While multiple possible staffing arrangements to admit patients exist, much debate centers around the traditional overnight “bolus” system vs a “drip” system. The traditional bolus system was described in this study; on the noncall days, interns advance care for the patients on their service and participate in education, occasionally leaving early if their work is done. In the drip system, 2 to 3 patients are admitted each day to an intern who does not stay overnight; while interns may be less fatigued and able to comply with duty hours, busier admitting days could lead to burnout and undermine education. Within a drip system, patients may have longer lengths of stay and worse quality of care, possibly due to increased handoffs.32,33 It is still unclear which system is better for resident education or patient safety.

A substantial proportion of shifts were not considered compliant with ACGME duty hours. The study took place immediately after duty-hour implementation, when programs were experimenting with how to comply with duty-hour restrictions; compliance was reported as suboptimal in a national study of residents.34 Since that time, programs have likely instituted interventions to improve compliance. For example, our program started a dayfloat service to assist postcall interns finish their work and leave in a timely fashion. Changes like these may partly explain the higher rates of compliance with duty hours reported by the ACGME.35

This study has several limitations. It was conducted in a single residency program at 1 institution, limiting generalizability. Our findings are most relevant for programs that use a bolus system for patient admissions and a traditional-extended, duty-shift model. While work intensification may still be a problem in a modified bolus system that uses 16-hour rotating call shifts, the risk of sleep loss is substantially lower when compared with the traditional bolus model with shifts in excess of 24 hours.36

Missing sleep and shift duration data may have resulted in systematic bias. However, there were no differences in workload on nights for which sleep or shift duration data were missing compared with present. Analyses performed after imputation of missing data yielded similar results. For the analysis of intern activity, the experience sampling method response rate appears low by conventional survey methods, but the participant burden makes the response fairly typical of experience sampling method studies.34 The data appear to be randomly missing because responses are distributed.
throughout the day, and there were no differences in response rates by intern, month, or day. It is possible that there are systematic differences in activities performed during times of missing data vs those performed for which there are observed data, leading to a biased estimate of that category. We do not have information on nighttime activities. It is somewhat reassuring that previous direct observation studies of on-call medical interns also reported similar proportions of time for education and indirect patient care.37,38

Paging logs may not accurately reflect the hours worked by the residents. Interns may have forgotten to sign out their pagers, resulting in an overestimation of their time worked. However, in this case an intern would continue to be paged, which would quickly serve as a reminder to forward the pager. Interns may have signed out their pagers but remained at the hospital to finish work, leading to an underestimation of hours worked.

Patient charts may have been abstracted incorrectly for the intern’s name, particularly when house staff services switched. This would only have affected the estimate of remaining patients on call. To minimize this error, accuracy checks were performed using intern charts.

We did not examine total weekly sleep or account for chronic partial sleep deprivation. The acuity and timing of the admission of patients was not examined, but could have affected hours worked and minutes slept. Because this was a secondary unplanned analysis of data initially collected for a different study, our study is limited by the observational design, sample size, and types of data available for this analysis. For example, we could not examine associations between workload and patient outcomes due to limitations in power.

Despite these limitations, our findings suggest that research is needed to understand workload effects on clinical outcomes, especially in shorter shift systems in which sleep loss is less of a concern. There is a paucity of studies exploring this area and a heightened interest in optimizing resident schedules to improve resident health and patient safety. These findings may help inform program changes and policies designed to reduce resident sleep deprivation and improve duty-hour compliance.

Author Contributions: Dr Arora had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Study concept and design:** Arora, Woodruff, Humphrey, Melzter.

**Acquisition of data:** Arora, Georgitis, Vekhter, Melzter.

**Analysis and interpretation of data:** Arora, Georgitis, Siddique, Humphrey, Melzter.

**Drafting of the manuscript:** Arora, Georgitis, Siddique, Vekhter, Woodruff, Humphrey, Melzter.

**Critical revision of the manuscript for important intellectual content:** Arora, Georgitis, Siddique, Vekhter, Woodruff, Humphrey, Melzter.

**Statistical analysis:** Arora, Georgitis, Siddique, Vekhter.

**Obtain of funding:** Arora, Woodruff, Humphrey, Melzter.

**Administrative, technical, or material support:** Arora, Georgitis, Vekhter, Woodruff, Humphrey, Melzter.

**Study supervision:** Arora, Humphrey, Melzter.

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To arrive at knowledge slowly, by one’s own experience, is better than to learn by rote, in a hurry, facts that other people know, and then, be glutted with words, to lose one’s own free, observant and inquisitive ability to study.
—Johann Heinrich Pestalozzi (1746-1827)