CLINICAL RESEARCH STUDY

THE AMERICAN JOURNAL of MEDICINE®

Patient Outcomes when Housestaff Exceed 80 Hours per Week

David Ouyang, MD,[a] Jonathan H. Chen, MD, PhD,[b] Gomathi Krishnan, PhD,[c] Jason Hom, MD,[a] Ronald Witteles, MD,[a] Jeffrey Chi, MD[a]

[a]Department of Internal Medicine, Stanford University School of Medicine, Calif; [b]Center for Innovation to Implementation, Veterans Affairs Palo Alto Health Care System, Calif; [c]Stanford Center for Clinical Informatics, Stanford University School of Medicine, Calif.

ABSTRACT

BACKGROUND: It has been posited that high workload and long work hours for trainees could affect the quality and efficiency of patient care. Duty hour restrictions seek to balance patient care and resident education by limiting resident work hours. Through a retrospective cohort study, we investigated whether patient care on an inpatient general medicine service at a large academic medical center is impacted when housestaff work more than 80 hours per week.

METHODS: We identified all admissions to a housestaff-run general medicine service between June 25, 2013 and June 29, 2014. Each hospitalization was classified by whether the patient was admitted by housestaff who have worked more than 80 hours per week during their hospitalization. Housestaff computer activity and duty hours were calculated by institutional electronic heath record audit, as well as length of stay and a composite of in-hospital mortality, intensive care unit (ICU) transfer rate, and 30-day readmission rate.

RESULTS: We identified 4767 hospitalizations by 3450 unique patients; of which 40.9% of hospitalizations were managed by housestaff who worked more than 80 hours that week during their hospitalization. There was a significantly higher rate of the composite outcome (19.2% vs 16.7%, $P = .031$) for patients admitted by housestaff working more than 80 hours per week during their hospitalization. We found a statistically significant higher length of stay (5.12 vs 4.66 days, $P = .048$) and rate of ICU transfer (3.53% vs 2.38%, $P = .029$). There was no statistically significant difference in 30-day readmission rate (13.7% vs 12.8%, $P = .395$) or in-hospital mortality rate (3.18% vs 2.42%, $P = .115$). There was no correlation with team census on admission and patient outcomes.

CONCLUSIONS: Patients taken care of by housestaff working more than 80 hours per week had increased length of stay and number of ICU transfers. There was no association between resident work-hours and patient in-hospital mortality or 30-day readmission rate.

© *2016 Elsevier Inc. All rights reserved.* • *The American Journal of Medicine (2016) 129, 993-999*

KEYWORDS: Duty hours; Electronic health record; Medical education; Readmissions

Over the last 13 years, the Accreditation Council for Graduate Medical Education (ACGME) has placed limitations on resident work hours. These regulations were intended to limit resident sleep loss and fatigue, with a goal of minimizing errors in patient care and improving high-yield education.[1-4] Such changes were not without

Funding: JHC was supported in part by VA Office of Academic Affiliations and Health Services Research and Development Service Research funds and the National Institute of Environmental Health Sciences of the National Institutes of Health under award number K01ES026837. Patient data extracted and de-identified by GK of the STRIDE (Stanford Translational Research Integrated Database Environment) project, a research and development project at Stanford University to create a standards-based informatics platform supporting clinical and translational research. The STRIDE project described was supported by the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through grant UL1 RR025744.

Conflict of Interest: None.

Authorship: DO, JHC, and JC had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Requests for reprints should be addressed to Jeffrey Chi, MD, Stanford University School of Medicine, Department of Internal Medicine, Stanford, CA 94305.

E-mail address: jeffrey.chi@stanford.edu

0002-9343/$ -see front matter © 2016 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.amjmed.2016.03.023

controversy: concerns have subsequently been raised about the adoption of "shift mentality," decreased experience in patient care, and inexperience in handoffs leading to errors in patient care.[1] Additionally, changes in resident work-structure have the potential to cause unforeseen consequences, including an increased number of patient care handoffs and increased attending physician workloads.[2]

Notably, duty hour standards were adopted without high-quality evidence suggesting benefit to patient care or safety.[3-6] Large studies using national patient samples immediately after the institution of ACGME resident duty hour limits failed to show significant change in the quality or safety of inpatient care,[7-9] though these studies did not directly track resident work hours. Rather, these studies primarily examined differences in patient outcomes based on changes in resident team structures and schedules implemented to adhere to ACGME duty hour standards. A recent study at an internal medicine program also did not show any increase in adverse events with discontinuity of care.[10] Large randomized studies of surgical training programs have not shown any significant difference in patient care or trainee well-being, and a similar trial involving internal medicine programs is still underway.[11,12] Although we are now more than a decade out from the implementation of duty hour standards, these requirements and their implications remain controversial and insufficiently studied.

One important limitation of monitoring and studying of resident duty hours has been a reliance on self-reported data, which can be prone to individual manipulation or recall bias, and residents are implicitly incentivized to avoid duty hour violations. When compared against independent, objective data, self-reported duty hours are often inconsistent and can underestimate duty hour violations.[13-15] In the present study, we sought to determine the association between resident duty hours and the quality of patient care by directly correlating resident work hours, as determined by electronic health record usage, with the clinical outcomes of the patients they manage.

CLINICAL SIGNIFICANCE

- Increases in patient length of stay and transfers to the ICU are associated with housestaff working in excess of 80 hours per week.
- No significant increase in patient mortality or readmission rates occur when housestaff exceed 80 hours per week.
- Under current ACGME guidelines, increases in resident team census have no significant effect on length of stay, mortality, readmissions, or ICU transfers.

METHODS

Study Design and Setting

We conducted a retrospective cohort study of all patients admitted to the inpatient general medicine service of a large academic medical center in Stanford, California between June 25, 2013 and June 29, 2014.[16] The general medicine service is the largest service at this academic teaching hospital, with 5 teams each comprising 2 interns, 1 senior resident, and an attending physician. Teams rotate on a 5-day call cycle, admitting new patients from 7 AM to 7 PM on the first and fourth days of the schedule. Patients were matched to housestaff by team assignment and classified by whether either the intern or supervising resident worked more than 80 hours during the week of admission. Patients who were initially admitted to the intensive care service then subsequently transferred to medicine were excluded from this analysis. This study was approved by the Stanford University Institutional Review Board. The first 2 authors and the last author vouch for the validity of the data and analyses.

Resident Duty Hour Analysis and Data Source

Residents on the general medicine service were identified by residency program scheduling information, and electronic actions performed were extracted by institutional electronic health record audit. Our institution uses the EPIC Electronic Health Record system, and data were extracted with support from our institutional informatics platform.[17] Actions identified include, but were not limited to, viewing laboratory results, placing orders, performing medication reconciliation, and generating notes in the electronic health record. Total working time was calculated as the time difference between the first and last action recorded each day. The entire analysis was also repeated while excluding the first and last 5% of electronic actions each day to minimize the influence of outliers in resident behavior. Hours worked per week were calculated as the summation of daily working time for each calendar week from Sunday to Saturday. Activity from the night float team was excluded from the analysis. Team census was determined by identifying the number of unique patients taken care of by each inpatient medical team. Patient length of stay, mortality, transfer to the intensive care unit (ICU), and 30-day same-hospital readmission status were also obtained from the electronic health record.

Outcome Measures

The primary outcome was a composite of death, transfer from medicine team to the ICU, or 30-day same-hospital readmission, because these metrics reflect a complicated hospital course. Secondary outcomes included patient length of stay, in-hospital mortality, transfer to the ICU, and readmission within 30 days. Death and length of stay were directly ascertained from the dataset. Hospital admission times and discharge times were used to identify 30-day same-hospital readmissions. Intensive care unit transfers

were identified as patients that had a general medicine primary team assignment followed by a critical care primary team assignment.

Statistical Analysis

Patients were classified by whether they were admitted by either an intern or supervising resident working more than 80 hours per week during the week of their initial team assignment. Baseline characteristics of age, sex, race, average household income by ZIP code, and Medicare diagnosis-related group case mix index were calculated for each group. The primary composite outcome, length of stay, in-hospital mortality, ICU transfer rate, and 30-day same-hospital readmission rates were also calculated for each group. Between-group comparisons were performed with the use of Student's t test for continuous variables and the χ^2 test for categorical variables. Hospitalization-specific variables included team census on admission, time of the year, and the amount of computer usage as characterized by the total computer time and the number of electronic actions performed per day. All analyses were performed using Python 2.7 (Python Software Foundation, Beaverton, OR) and R 3.2.2 (R Foundation, Vienna, Austria). Statistical tests were performed with a 2-sided significance threshold of .05.

RESULTS

Resident Work Hours and Workload

We identified 91 internal medicine residents on the general medicine service between June 25, 2013 and June 29, 2014. During this period, housestaff treated 3450 unique patients over 4767 individual hospitalizations while performing 4,327,708 unique actions on the electronic health record. Over a 4-week rotation, interns worked a median of 64.9 (interquartile range 52.1-75.6) hours per week and residents worked 70.9 (interquartile range 55.0-83.1) hours per week. However, 21.3% of calculated work week hours exceeded 80 hours for a given week. In all, 40.9% of patients were treated by at least 1 house officer who had worked more than 80 hours that week (Figure 1). There was no significant difference in the

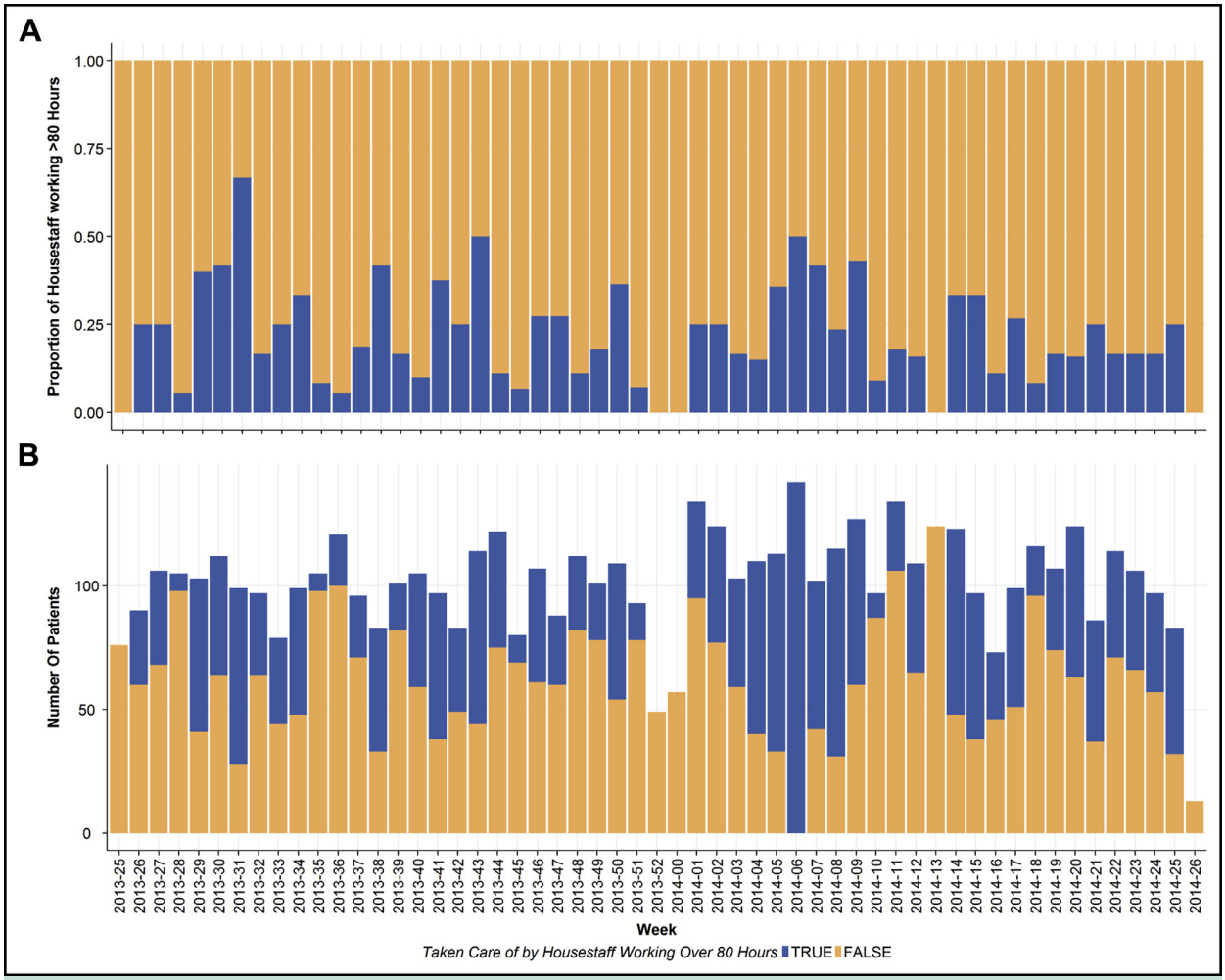

Figure 1 (**A**) Housestaff worked more than 80 hours per week in 21.3% of calculated weeks. There was no relationship between time to start of residency year and proportion of residents working more than 80 hours per week ($P = .740$). (**B**) 40.9% of patients were taken care of by housestaff that had worked more than 80 hours that week.

proportion of residents working more than 80 hours per week according to the time of year ($P = .740$). Higher team census was associated with more hours worked per day, more electronic actions, and more computer sessions (Figure 2, $P < .001$ for trend for each comparison); however, there was no statistically significant trend in outcomes of length of stay, 30-day readmission rates, ICU transfers, or in-hospital mortality with team census on admission (Figure 3).

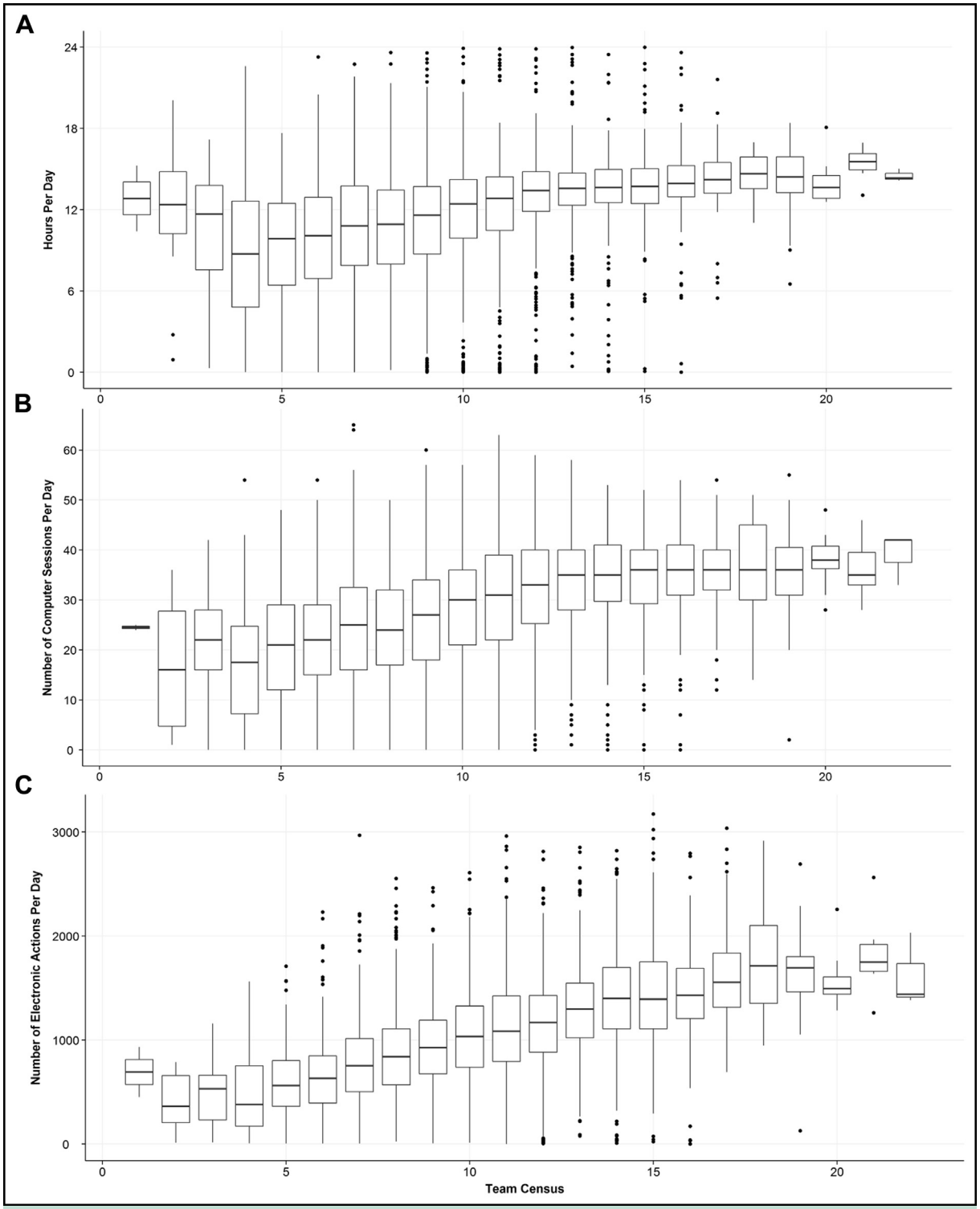

Figure 2 (**A**) There is an increase in the daily hours worked by housestaff as team census increases ($P < .001$). (**B**) There is an increase in the number of computer sessions by housestaff as team census increases ($P < .001$). (**C**) There is an increase in the number of electronic actions by housestaff as team census increases ($P < .001$).

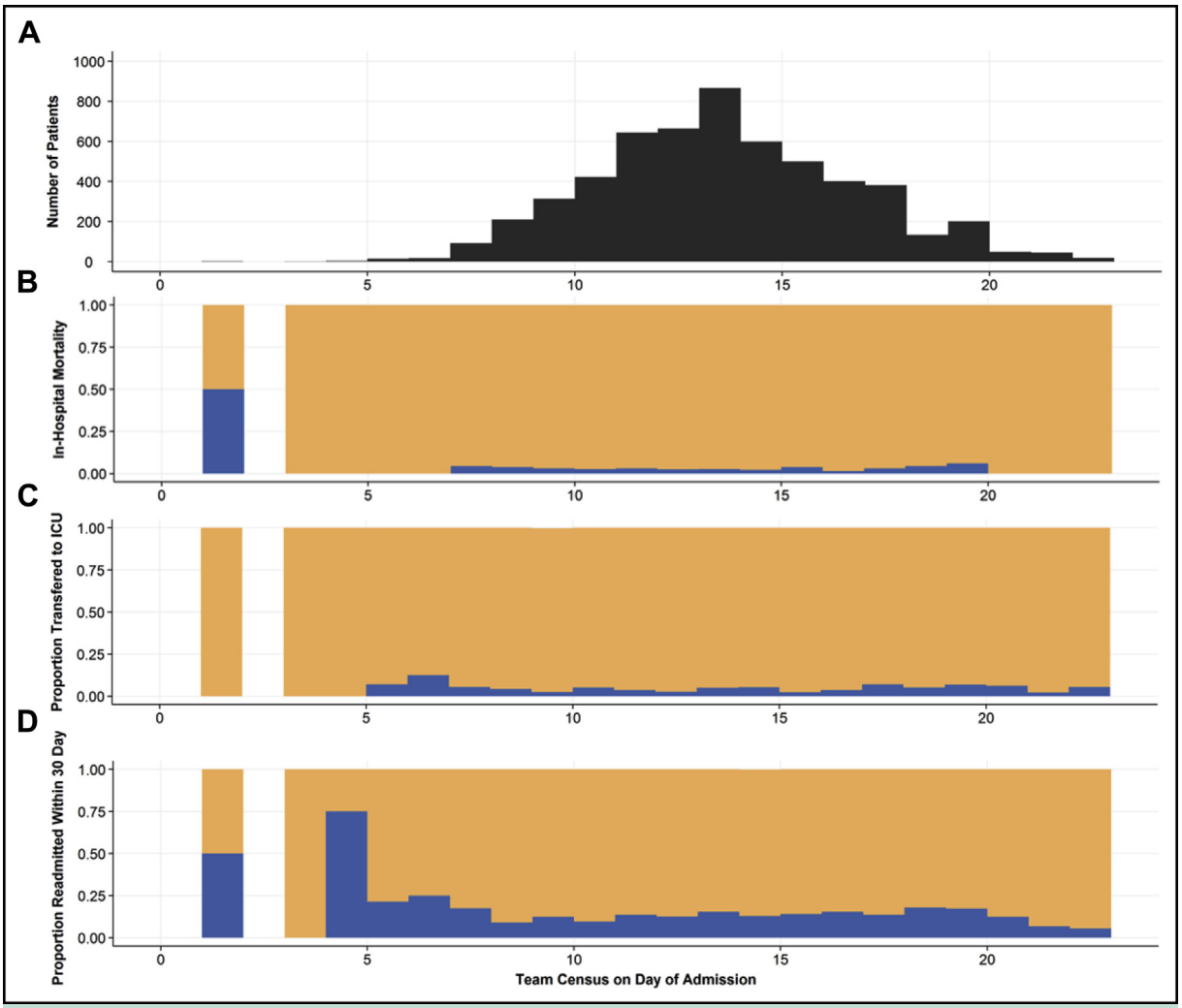

Figure 3 (**A**) Distribution of admission team census. (**B**) Proportion of in-hospital mortality by admission team census. (**C**) Proportion of intensive care unit (ICU) transfers. (**D**) Proportion of subsequent 30-day readmissions by admission team census.

Patient Population and Outcomes

The overall mean (SD) length-of-stay was 4.85 (7.63) days, and the in-hospital mortality rate was 2.71%. In the study population, 13.2% of patients had a 30-day same-hospital readmission, and the mean (SD) time from discharge to readmission was 14.0 (8.60) days. There was no statistically significant difference between the 2 groups in terms of patient age, sex ratio, case mix index (when available), race, or income by ZIP code (Table 1).

Comparing patients admitted to teams in which either the intern or resident worked more than 80 hours per week and teams in which no member worked more than 80 hours, there was a statistically significant difference in length of stay (5.12 vs 4.67 days, $P = .048$) and rate of ICU transfer (3.53% vs 2.42%, $P = .029$). There was no statistically significant difference in 30-day readmission rate (13.68% vs 12.79%, $P = .395$), or in-hospital mortality rate (3.18% vs 2.38%, $P = .115$) (Table 2).

To eliminate the possibility of outlier behavior influencing the results, the entire analysis was repeated with the exclusion of the last 5% of actions each day and with the exclusion of both the first and last 5% of actions each day (Supplementary Tables 1 and 2, available online).

Although this decreased the sample size of patients admitted by residents working more than 80 hours each week, there were only minor differences in the statistical significance of the primary outcome, in-hospital mortality, ICU transfer rate, and 30-day readmission rates.

Post hoc power calculations suggest that a sample size of 1769 patients in each group would be sufficient to identify a 0.8-day difference in length of stay and a sample size of 1887 patients in each group to identify a 3% difference in readmission rates with a power of 0.80 and α of 0.05. A sample size of 1859 in each group would be needed to identify a 1.5% difference in in-hospital mortality with a power of 0.80 and α of 0.05.

Table 1 Baseline Characteristics

Characteristic	>80 h/wk (n = 1952)	Control Group (n = 2815)	*P* Value
Patient age (y), mean (SD)	60.9 (19.4)	60.3 (19.7)	.304
Female sex, n (%)	1002 (51.3)	1458 (52.0)	.682
No. of patients with DRG, n (%)	1646 (84.3)	2376 (84.4)	.980
Case mix index, mean (SD)	1.54 (1.63)	1.47 (1.46)	.127
Race, n (%)			.700
White	955 (48.9)	1389 (49.3)	
Black	177 (9.1)	272 (9.7)	
Asian/Pacific Islander	329 (16.9)	445 (15.8)	
Native American	5 (0.0)	12 (0.0)	
Other or unknown	486 (24.9)	697 (24.8)	
Income by ZIP code, n (%)			.998
First quartile	682 (34.9)	994 (35.3)	
Second quartile	910 (46.6)	1305 (46.4)	
Third quartile	302 (15.5)	432 (15.3)	
Fourth quartile	1 (0.0)	2 (0.0)	
Unknown	57 (2.9)	82 (2.9)	

DRG = diagnosis-related group.

DISCUSSION

Increased physician workload has been hypothesized to lead to excess errors, including delayed response to abnormal test results and prescribing errors, which have the potential to lead to increased morbidity and mortality.[18] Although prior studies have examined the role of handoffs and the impact of ward structure changes in the most recent duty hour regulations,[19,20] the specific impact of resident hours on patient care has not been well studied. Despite new ward structures and best efforts, trainees may continue to engage in patient care beyond the knowledge of training programs.[15]

The primary finding of this study was the association between increased housestaff work hours and increased patient length of stay and increased rate of ICU transfers. Although there is limited evidence to suggest 80 hours as a unique threshold, we found differences in patient outcomes when identifying patients who were and were not managed by housestaff working more than 80 hours per week. Our study suggests that duty hour restrictions, initiated with the premise of improving patient safety, can predict and influence patient outcomes.

Table 2 Clinical Outcomes for Patients Taken Care of by Housestaff Working More Than 80 Hours per Week

Outcome	>80 h/wk (n = 1952)	Control Group (n = 2815)	*P* Value
Length of stay (days), mean (SD)	5.12 (8.20)	4.66 (7.2)	.04796*
Composite endpoint, n (%)	374 (19.16)	470 (16.70)	.0314*
In-hospital mortality, n (%)	62 (3.18)	67 (2.38)	.1152
Transfer to ICU, n (%)	69 (3.53)	68 (2.42)	.0288*
30-Day readmission, n (%)	267 (13.68)	360 (12.79)	.3953

ICU = intensive care unit.
*$P < .05$.

These findings were found in parallel with higher team censuses being related to increased resident work hours and computer activity. There was not a direct relationship between team census and patient length of stay, readmission rate, or in-hospital mortality, and these outcomes remained stable throughout a range of team censuses, which suggests that a high number of low-complexity patients can be taken care of just as well as a low number of high-complexity patients but that excess work hours are most associated with patient clinical outcomes. Negative outcomes such as death or readmission rates were perhaps mitigated by the academic team structure in which multiple physicians are involved in the care of each patient and may potentially minimize errors or improve response time to urgent situations. Additionally, larger academic centers may have more robust support systems (including discharge pharmacists, case managers, and social workers) that support and effectively offload physician responsibilities when there are higher patient censuses.

Our study has several limitations. This analysis is limited to 1 medical service at 1 academic center, though this is the largest admitting service at our institution, with more than 4000 admissions each year. The association of workload and outcomes is likely context dependent, with different hospital systems and training programs having different call schedules, different team structures, varying degrees of support from ancillary staff, and differing patient populations. In this study we did not exclude mobile remote electronic health record access because it only accounted for 0.49% of EPIC actions and did not significantly change the analysis or conclusions. In calculating resident work hours, we examined the aggregate number of hours worked by identifying the range between the first and the last action each day. Although we cannot exclude the possibility of residents briefly accessing the medical record at the beginning or end of the day, skewing the calculated hours worked, our analysis produced consistent results when excluding the earliest and latest set of actions performed each day (Supplementary Tables 1 and 2, available online). Such sensitivity analysis did not produce different results across a range of exclusion parameters. Finally, although precise, time spent on the computer is likely a lower bound estimate of resident work hours and may not capture other forms of indirect patient care or time spent at the patient bedside before the first electronic action or after the last electronic action.

This study represents the first large-scale attempt, to our knowledge, to study associations between resident work-hour electronic health record data and patient outcomes on an inpatient service. Further work in the form of randomized, site-controlled studies are currently underway to understand the relationship between resident work hours and patient outcomes; however, retrospective analysis of electronic health record data can offer a complementary method for rapid, cost-effective, and objective review of true resident work hours not biased by recall bias or the Hawthorne

effect.[10,11] Working additional hours or carrying high patient censuses more frequently or for longer periods of time may lead to increased resident burn-out, decreased well-being, and decreased efficiency that are only exhibited after prolonged periods. Additional focus on resident education and patient outcomes as they relate to duty hours will hopefully increase clarity, reduce controversy, and help guide future ACGME policy decisions in an informed manner.

References

1. Nasca TJ, Day SH, Amis ES. ACGME Duty Hour Task Force. The new recommendations on duty hours from the ACGME Task Force. *N Engl J Med*. 2010;363(2):e3.
2. Michtalik HJ, Yeh HC, Pronovost PJ, Brotman DJ. Impact of attending physician workload on patient care: a survey of hospitalists. *JAMA Intern Med*. 2013;173(5):375-377.
3. Fletcher KE, Reed DA, Arora VM. Patient safety, resident education and resident well-being following implementation of the 2003 ACGME duty hour rules. *J Gen Intern Med*. 2011;26(8):907-919.
4. Fletcher KE, Underwood W, Davis SQ, Mangrulkar RS, McMahon LF, Saint S. Effects of work hour reduction on residents' lives: a systematic review. *JAMA*. 2005;294(9):1088-1100.
5. Bilimoria KY, Hoyt DB, Lewis F. Making the case for investigating flexibility in duty hour limits for surgical residents. *JAMA Surg*. 2015;150(6):503-504.
6. Lerner BH. A case that shook medicine. The Washington Post. Available at: www.washingtonpost.com/wp-dyn/content/article/2006/11/24/AR2006112400985.html. 2006. Accessed October 8, 2015.
7. Volpp KG, Rosen AK, Rosenbaum PR, et al. Did duty hour reform lead to better outcomes among the highest risk patients? *J Gen Intern Med*. 2009;24(10):1149-1155.
8. Volpp KG, Rosen AK, Rosenbaum PR, et al. Mortality among patients in VA hospitals in the first 2 years following ACGME resident duty hour reform. *JAMA*. 2007;298(9):984-992.
9. Volpp KG, Rosen AK, Rosenbaum PR, et al. Mortality among hospitalized Medicare beneficiaries in the first 2 years following ACGME resident duty hour reform. *JAMA*. 2007;298(9):975-983.
10. Fletcher KE, Singh S, Schapira MM, et al. Inpatient housestaff discontinuity of care and patient adverse events. *Am J Med*. 2016;129(3):341-347.e21.
11. Bilimoria KY, Chung JW, Hedges LV, et al. National cluster randomized trial of duty-hour flexibility in surgical training. *N Engl J Med*. 2016;374(8):713-727.
12. American Academy of Family Physicians. Resident duty hour rules focus of national research trials now set to launch. Available at: www.aafp.org/news/education-professional-development/20140415dutyhourstudy.html. 2014. Accessed October 12, 2015.
13. Todd SR, Fahy BN, Paukert JL, Mersinger D, Johnson ML, Bass BL. How accurate are self-reported resident duty hours? *J Surg Educ*. 2010;67(2):103-107.
14. Buum HA, Duran-Nelson AM, Menk J, Nixon LJ. Duty-hours monitoring revisited: self-report may not be adequate. *Am J Med*. 2013;126(4):362-365.
15. Mourad M, Vidyarthi AR, Hollander H, Ranji SR. Shifting indirect patient care duties to after hours in the era of work hours restrictions. *Acad Med*. 2011;86(5):586-590.
16. Ouyang D, Chen JH, Hom J, Chi J. Internal medicine resident computer usage: an electronic audit of an inpatient service. *JAMA Intern Med*. 2016;176(2):252-254.
17. Lowe HJ, Ferris TA, Hernandez PM, Weber SC. STRIDE—an integrated standards-based translational research informatics platform. *AMIA Annu Symp Proc*. 2009;2009:391-395.
18. Elliott DJ, Young RS, Brice J, Aguiar R, Kolm P. EFfect of hospitalist workload on the quality and efficiency of care. *JAMA Intern Med*. 2014;174(5):786-793.
19. Pepper DJ, Schweinfurth M, Herrin VE. The effect of new duty hours on resident academic performance and adult resuscitation outcomes. *Am J Med*. 2014;127(4):337-342.
20. Denson JL, McCarty M, Fang Y, Uppal A, Evans L. Increased mortality rates during resident handoff periods and the effect of ACGME duty hour regulations. *Am J Med*. 2015;128(9):994-1000.

SUPPLEMENTARY DATA

Supplementary tables accompanying this article can be found in the online version at http://dx.doi.org/10.1016/j.amjmed.2016.03.023.

APPENDIX

Supplementary Table 1 Clinical Outcomes for Patients Taken Care of by Housestaff Working More Than 80 Hours per Week (Excluding the Last 5% of Actions Performed Each Day)

Outcome	>80 h/wk (n = 1283)	Control Group (n = 3484)	*P* Value
Composite endpoint, n (%)	261 (22.23)	583 (16.23)	.0043*
In-hospital mortality, n (%)	46 (3.59)	83 (2.38)	.0300*
Transfer to ICU, n (%)	48 (4.09)	89 (2.48)	.0102*
30-Day readmission, n (%)	185 (15.76)	442 (12.30)	.1281

ICU = intensive care unit.
*$P < .05$.

Supplementary Table 2 Clinical Outcomes for Patients Taken Care of by Housestaff Working More Than 80 Hours per Week (Excluding the First and Last 5% of Actions Performed Each Day)

Outcome	>80 h/wk (n = 1174)	Control Group (n = 3593)	*P* Value
Composite endpoint, n (%)	233 (19.80)	611 (17.00)	.0300*
In-hospital mortality, n (%)	41 (3.49)	88 (2.45)	.0705
Transfer to ICU, n (%)	47 (4.00)	90 (2.50)	.0102*
30-Day readmission, n (%)	161 (13.70)	466 (13.00)	.545

ICU = intensive care unit.
*$P < .05$.