

Supplemental Material

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Analyses by cohort. The results in both cohorts are similar to the combined cohort presented in the main paper. The 2002-2007 data set contributes relatively less data to the overall analysis (~10,000 fewer monthly surveys) and lacks statistical power to estimate the association for less frequent outcomes. The observed associations are similar in each cohort, but for subsets of outcomes (e.g., adverse events from the larger category of medical errors) the model does not converge when using only data from cohort 1.

Table S1a. The adjusted association between increasing weekly work hours and adverse health and safety outcomes among PGY2+ resident physicians from 2002-2007.

	Weekly Work Hours					p-value
	≤48	>48 & ≤60	>60 & ≤70	>70 & ≤80	>80	
Patient Safety						
Medical Errors	Ref	1.55 (1.22-1.97)	2.18 (1.71-2.77)	3.23 (2.49-4.18)	4.23 (3.20-5.57)	<0.001
PAE	Ref	---	---	---	---	---
Fatal PAE	Ref	---	---	---	---	---
Resident Safety						
Crashes	Ref	---	---	---	---	---
Crashes leaving work	Ref	---	---	---	---	---
Near-crashes	Ref	1.23 (1.00-1.50)	1.38 (1.11-1.71)	1.74 (1.40-2.17)	2.65 (2.14-3.28)	<0.001
Occupational Exposures	Ref	1.78 (1.36-2.32)	2.50 (1.92-3.25)	3.56 (2.74-4.63)	4.48 (3.41-5.90)	<0.001
Percutaneous Injuries	Ref	---	---	---	---	---
Attentional Failures	Ref	1.41 (1.28-1.55)	2.09 (1.87-2.33)	2.72 (2.44-3.03)	3.71 (3.32-4.16)	<0.001

All models are adjusted for age, gender, specialty, and cohort. Occupational exposures, percutaneous injuries, and patient safety outcomes are further adjusted for hours in patient care. P-values are obtained from likelihood ratio tests testing a linear trend through the categories.

Table S1b. The adjusted association between increasing weekly work hours and adverse health and safety outcomes among PGY2+ resident physicians from 2015-2017.

	Weekly Work Hours					p-value
	≤48	>48 & ≤60	>60 & ≤70	>70 & ≤80	>80	
Patient Safety						
Medical Errors	Ref	1.67 (1.38-2.03)	2.52 (2.03-3.13)	3.18 (2.54-3.98)	3.79 (2.91-4.93)	<0.001
PAE	Ref	1.63 (0.97-2.75)	3.91 (2.36-6.50)	3.31 (1.91-5.73)	4.84 (2.58-9.08)	<0.001
Fatal PAE	Ref	0.74 (0.10-5.27)	6.93 (1.48-32.51)	5.28 (0.99-28.17)	16.05 (2.99-86.03)	<0.001
Resident Safety						
Crashes	Ref	0.96 (0.70-1.30)	1.01 (0.71-1.42)	0.94 (0.66-1.36)	1.30 (0.85-1.99)	0.75
Crashes leaving work	Ref	0.98 (0.57-1.71)	1.10 (0.60-2.01)	1.17 (0.63-2.16)	2.41 (1.29-4.53)	0.25
Near-crashes	Ref	1.61 (1.33-1.94)	2.17 (1.76-2.68)	2.54 (2.05-3.15)	3.31 (2.57-4.27)	<0.001
Occupational Exposures	Ref	1.78 (1.35-2.33)	2.41 (1.83-3.17)	3.10 (2.34-4.11)	3.81 (2.73-5.30)	<0.001
Percutaneous Injuries	Ref	1.70 (1.16-2.51)	1.97 (1.32-2.94)	2.82 (1.87-4.23)	5.29 (3.47-8.07)	<0.001
Attentional Failures	Ref	1.29 (1.22-1.37)	1.67 (1.55-1.80)	2.08 (1.90-2.29)	2.71 (2.45-2.98)	<0.001

All models are adjusted for age, gender, specialty, and cohort. Occupational exposures, percutaneous injuries, and patient safety outcomes are further adjusted for hours in patient care. P-values are obtained from likelihood ratio tests testing a linear trend through the categories.

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Table S2. The incidence of outcomes by weekly work hour categories

	Weekly Work Hours				
	≤48	>48 & ≤60	>60 & ≤70	>70 & ≤80	>80
Patient Safety					
Medical Error rate	3.02	5.02	7.87	10.80	14.33
PAE rate	0.47	0.78	1.69	1.82	2.78
Fatal PAE rate	0.10	0.07	0.36	0.33	0.68
Resident Safety					
Crash rate	1.52	1.41	1.51	1.48	1.99
Crashes leaving work rate	0.55	0.52	0.53	0.52	1.06
Near-crash rate	5.71	7.81	9.91	12.03	17.87
Occupational Exposure rate	1.57	2.71	3.86	5.42	7.40
Percutaneous Injury rate	0.68	1.13	1.74	2.42	4.24
Attentional Failure rate	84.45	119.00	157.46	212.64	301.66

All estimates expressed in rate per 100 person-months.

Table S3: The incidence of outcomes by exposures of interest.

	Weekly Work Hours (WWH)		Extended-duration Shifts (EDS)			Combined categorical WWH and EDS			
	≤80	>80	None	1-4	≥5	≤80 WWH No EDS	≤80 WWH ≥1 EDS	>80 WWH No EDS	>80 WWH ≥1 EDS
Patient Safety									
Medical Errors	6.23	14.33	4.90	8.28	14.50	4.54	9.63	12.12	14.93
PAE	1.10	2.78	0.92	1.42	2.48	0.84	1.61	3.03	2.71
Fatal PAE	0.19	0.68	0.14	0.29	0.55	0.12	0.32	0.66	0.68
Crashes	1.47	1.99	1.38	1.70	1.85	1.39	1.65	1.28	2.19
Crashes leaving work	0.53	1.06	0.47	0.71	0.89	0.46	0.67	0.51	1.22
Near-crashes	8.52	17.87	7.49	10.36	16.33	7.35	10.92	11.55	19.67
Occupational Exposures	3.19	7.40	2.81	4.25	5.88	2.71	4.13	5.68	7.86
Percutaneous Injuries	1.39	4.24	1.25	1.97	2.96	1.20	1.78	2.78	4.64
Attentional Failures	136.33	301.66	123.36	168.55	251.26	118.37	172.68	266.10	311.62

All estimates expressed in rate per 100 person-months.

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Table S4a: The adjusted association between increasing weekly work hours and adverse health and safety outcomes *with missing age imputed using the median value for each cohort.*

	Weekly Work Hours					p-value
	≤48	>48 & ≤60	>60 & ≤70	>70 & ≤80	>80	
Patient Safety						
Medical Errors	Ref	1.61 (1.39-1.87)	2.36 (2.01-2.78)	3.19 (2.69-3.78)	4.01 (3.32-4.84)	<0.001
PAE	Ref	1.54 (1.06-2.24)	2.93 (2.04-4.23)	2.84 (1.93-4.19)	3.84 (2.51-5.87)	<0.001
Fatal PAE	Ref	0.66 (0.25-1.70)	2.75 (1.23-6.12)	2.51 (0.87-5.30)	3.67 (1.45-9.30)	<0.001
Resident Safety						
Crashes	Ref	0.93 (0.74-1.19)	0.99 (0.76-1.28)	0.94 (0.72-1.24)	1.24 (0.92-1.66)	0.49
Crashes leaving work	Ref	0.96 (0.66-1.41)	0.96 (0.62-1.47)	0.92 (0.59-1.43)	1.78 (1.15-2.76)	0.13
Near-crashes	Ref	1.41 (1.23-1.61)	1.77 (1.52-2.06)	2.11 (1.81-2.46)	2.97 (2.52-3.50)	<0.001
Occupational Exposures	Ref	1.78 (1.48-2.16)	2.46 (2.03-2.98)	3.35 (2.77-4.06)	4.19 (3.39-5.17)	<0.001
Percutaneous Injuries	Ref	1.71 (1.28-2.28)	2.59 (1.95-3.44)	3.49 (2.62-4.64)	5.80 (4.32-7.79)	<0.001
Attentional Failures	Ref	1.33 (1.27-1.40)	1.80 (1.69-1.92)	2.29 (2.13-2.46)	3.06 (2.85-3.30)	<0.001

All models are adjusted for age, gender, specialty, and cohort. Occupational exposures, percutaneous injuries, and patient safety outcomes are further adjusted for hours in patient care. P-values are obtained from likelihood ratio tests testing a linear trend through the categories.

Table S4b: The adjusted association between increasing weekly work hours and adverse health and safety outcomes *among those with complete information (no missing values).*

	Weekly Work Hours					p-value
	≤48	>48 & ≤60	>60 & ≤70	>70 & ≤80	>80	
Patient Safety						
Medical Errors	Ref	1.59 (1.37-1.85)	2.37 (2.02-2.79)	3.23 (2.73-3.83)	4.15 (3.43-5.02)	<0.001
PAE	Ref	1.59 (1.08-2.32)	2.94 (2.03-4.26)	2.91 (1.96-4.32)	3.92 (2.55-6.04)	<0.001
Fatal PAE	Ref	---	---	---	---	
Resident Safety						
Crashes	Ref	0.96 (0.76-1.22)	0.97 (0.74-1.28)	0.97 (0.73-1.30)	1.27 (0.93-1.72)	0.53
Crashes leaving work	Ref	0.96 (0.65-1.41)	0.87 (0.55-1.35)	0.82 (0.50-1.34)	1.69 (1.07-2.68)	0.11
Near-crashes	Ref	1.42 (1.24-1.63)	1.77 (1.51-2.07)	2.14 (1.82-2.51)	3.05 (2.57-3.62)	<0.001
Occupational Exposures	Ref	1.71 (1.40-2.10)	2.18 (1.78-2.67)	2.67 (2.17-3.29)	3.19 (2.54-4.01)	<0.001
Percutaneous Injuries	Ref	1.64 (1.21-2.23)	2.29 (1.68-3.11)	2.62 (1.91-3.59)	3.75 (2.71-5.18)	<0.001
Attentional Failures	Ref	1.35 (1.28-1.42)	1.83 (1.72-1.95)	2.28 (2.13-2.45)	3.00 (2.79-3.23)	<0.001

All models are adjusted for age, gender, specialty, and cohort. Occupational exposures, percutaneous injuries, and patient safety outcomes are further adjusted for hours in patient care. P-values are obtained from likelihood ratio tests testing a linear trend through the categories.

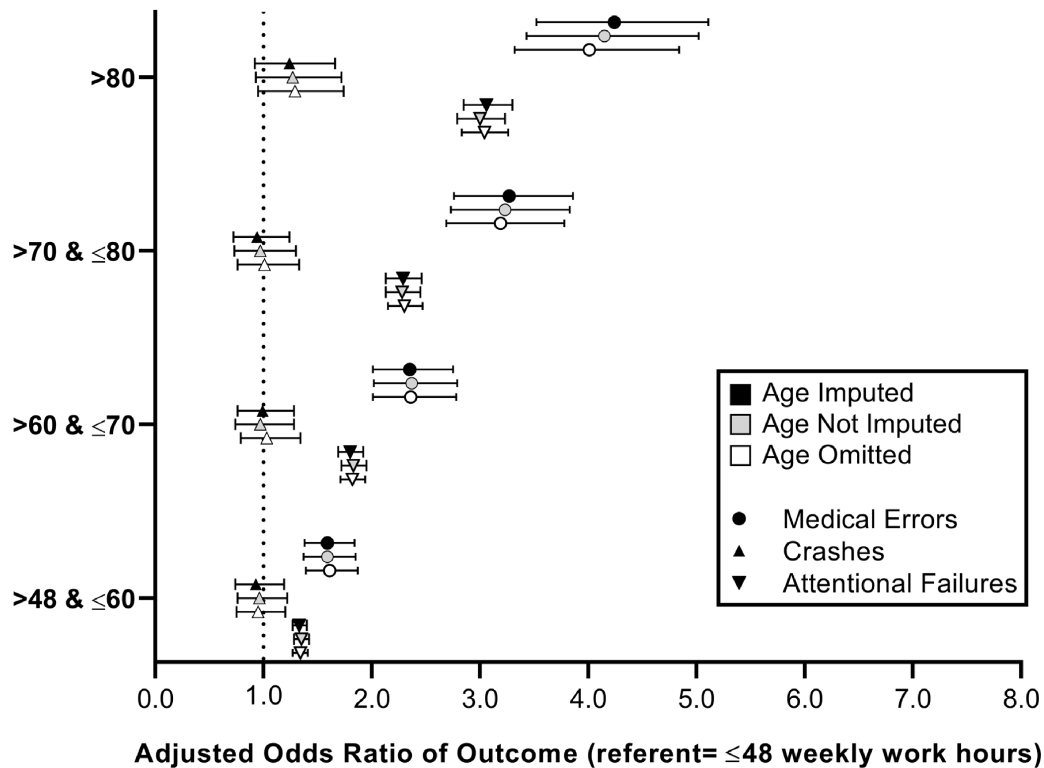
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Table S4c: The adjusted association between increasing weekly work hours and adverse health and safety outcomes *with age omitted from the statistical models.*

	Weekly Work Hours					p-value
	≤48	>48 & ≤60	>60 & ≤70	>70 & ≤80	>80	
Patient Safety						
Medical Errors	Ref	1.59 (1.38-1.84)	2.35 (2.01-2.75)	3.27 (2.76-3.86)	4.24 (3.52-5.11)	<0.001
PAE	Ref	1.55 (1.07-2.25)	3.02 (2.10-4.34)	2.98 (2.02-4.38)	4.04 (2.65-6.17)	<0.001
Fatal PAE	Ref	0.65 (0.25-1.69)	3.02 (1.35-6.75)	2.55 (1.02-6.38)	4.19 (1.62-10.87)	<0.001
Resident Safety						
Crashes	Ref	0.95 (0.75-1.20)	1.03 (0.79-1.34)	1.01 (0.76-1.33)	1.29 (0.95-1.74)	0.45
Crashes leaving work	Ref	0.96 (0.66-1.42)	0.96 (0.62-1.47)	0.94 (0.59-1.49)	1.76 (1.13-2.75)	0.15
Near-crashes	Ref	1.40 (1.23-1.60)	1.79 (1.54-2.09)	2.17 (1.85-2.54)	3.09 (2.61-3.66)	<0.001
Occupational Exposures	Ref	1.71 (1.40-2.09)	2.16 (1.77-2.64)	2.67 (2.17-3.27)	3.22 (2.58-4.04)	<0.001
Percutaneous Injuries	Ref	1.59 (1.18-2.14)	2.19 (1.62-2.95)	2.51 (1.84-3.41)	3.71 (2.70-5.08)	<0.001
Attentional Failures	Ref	1.34 (1.27-1.41)	1.82 (1.71-1.94)	2.30 (2.15-2.47)	3.04 (2.83-3.26)	<0.001

All models are adjusted for gender, specialty, and cohort. Occupational exposures, percutaneous injuries, and patient safety outcomes are further adjusted for hours in patient care. P-values are obtained from likelihood ratio tests testing a linear trend through the categories.

Figure S1: The adjusted association between increasing weekly work hours and adverse health and safety outcomes does not vary by treatment of age.



Supplemental Material

MONTHLY QUESTIONNAIRE**Work Schedule**

The following questions ask about your schedule in the month of [month] .

Note that there are 168 hours in one week (7 days x 24 hours). Please round to the nearest hour.

	First week of [month]	Second week of [month]	Third week of [month]	Fourth week of [month]
Activity that best describes the week (>4 days)	<input type="radio"/> Outpatient / ambulatory rotation <input type="radio"/> In-hospital consult rotation <input type="radio"/> Intensive care unit rotation <input type="radio"/> In-hospital ward rotation <input type="radio"/> Night team / night float <input type="radio"/> Emergency Department <input type="radio"/> Research <input type="radio"/> Elective <input type="radio"/> Vacation <input type="radio"/> Other	<input type="radio"/> Outpatient / ambulatory rotation <input type="radio"/> In-hospital consult rotation <input type="radio"/> Intensive care unit rotation <input type="radio"/> In-hospital ward rotation <input type="radio"/> Night team / night float <input type="radio"/> Emergency Department <input type="radio"/> Research <input type="radio"/> Elective <input type="radio"/> Vacation <input type="radio"/> Other	<input type="radio"/> Outpatient / ambulatory rotation <input type="radio"/> In-hospital consult rotation <input type="radio"/> Intensive care unit rotation <input type="radio"/> In-hospital ward rotation <input type="radio"/> Night team / night float <input type="radio"/> Emergency Department <input type="radio"/> Research <input type="radio"/> Elective <input type="radio"/> Vacation <input type="radio"/> Other	<input type="radio"/> Outpatient / ambulatory rotation <input type="radio"/> In-hospital consult rotation <input type="radio"/> Intensive care unit rotation <input type="radio"/> In-hospital ward rotation <input type="radio"/> Night team / night float <input type="radio"/> Emergency Department <input type="radio"/> Research <input type="radio"/> Elective <input type="radio"/> Vacation <input type="radio"/> Other
Timing of work that best describes the week (>4 days)	<input type="radio"/> Day team <input type="radio"/> Night team <input type="radio"/> Rotating <input type="radio"/> Irregular	<input type="radio"/> Day team <input type="radio"/> Night team <input type="radio"/> Rotating <input type="radio"/> Irregular	<input type="radio"/> Day team <input type="radio"/> Night team <input type="radio"/> Rotating <input type="radio"/> Irregular	<input type="radio"/> Day team <input type="radio"/> Night team <input type="radio"/> Rotating <input type="radio"/> Irregular
Hours spent <u>physically</u> awake in the hospital, classes, or workplace (exclude moonlighting for extra income)				
Hours spent working or studying outside of the hospital or workplace (e.g., at home or at the library) related to your program.				
Hours spent working at any other job outside of your program (including moonlighting)				
Hours of sleep <u>at</u> the workplace or hospital				
Hours of sleep <u>outside</u> of the workplace or hospital				

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Number of days off (i.e., a full 24 hour period)				
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In [MONTH], what was the longest number of continuous hours that you were actually physically at work?

Include protected time for sleep provided during an extended shift and round to the nearest hour

hours

In [MONTH], what was the longest number of continuous hours that you went without sleep?

Please round to the nearest hour

hours

In [Month], on average per week, how many hours were spent:

Participating in direct patient care (examining patients, writing notes, interpreting diagnostic tests/radiographic studies/pathology specimens, consulting with other physicians, etc.)	_____ hours
In the workplace in duties not directly related to patient care (other paperwork, scheduling tests, etc.)	_____ hours
In formal structured learning including classes/ laboratories/grand rounds	_____ hours
In self-directed learning outside of the workplace	_____ hours
Teaching students or house staff	_____ hours
In leisure activities outside of the hospital or workplace	_____ hours

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The following questions ask about your extended shifts during the month (≥ 24 hours continuous at work).

	First week of [month]	Second week of [month]	Third week of [month]	Fourth week of [month]
Number of extended shifts				
Average length of extended shift				
Number of these shifts covered by night float				
Average hours of night float coverage (per night)				
Average hours of sleep during these extended shifts				
Average number of times you were awakened from sleep per extended shift (e.g., paged)				

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Outcomes

In the month of [month], how many times did you nod off or fall asleep:

	Number of times you nodded off or fell asleep*	Check if not applicable
During lectures, seminars, or grand rounds	_____	<input type="radio"/> I didn't attend any that month
On the telephone	_____	
During rounds with the attending	_____	<input type="radio"/> I didn't do rounds with an attending that month
While talking to or examining patients	_____	<input type="radio"/> I didn't examine/talk with patients that month
During surgery	_____	<input type="radio"/> I didn't do surgeries that month
While driving	_____	<input type="radio"/> I didn't drive that month
While stopped in traffic	_____	

*Enter 0 for zero or none, unless the option does not apply (then leave blank).

For the following question, please answer only in terms of when you personally were driving.

In the month of [month], did you have any motor vehicle accidents or crashes (actual collisions) in which you were driving ?

- Yes
 No

In the month of [month], did you have any near-miss motor vehicle accidents or crashes (narrowly avoided property damage or bodily harm) in which you were driving?

- Yes
 No

In the month of [month], did you personally have an occupational exposure to potentially contaminated blood or other body fluid?

- Yes
 No

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In the month of [month], did you cause an occupational exposure to potentially contaminated blood or other body fluid to others?

- Yes
 No

In the month of [month], do you believe sleep deprivation or fatigue caused you to make a significant medical error (whether or not an adverse patient outcome occurred)?

- Yes
 No

If you answered No to M1, skip to the next section

Approximately how many errors did you have in the month of [month]?

errors

How many, if any, errors resulted in an adverse patient outcome?

Adverse outcomes

If 0, skip this section

Please confirm you had ___ [fill in response from M2] error(s) that resulted in ___ [fill in response from M3] adverse patient outcome(s)?

- Yes, that is correct
 No, I will correct my answer to the previous questions.

If 0, skip this section

How many, if any, errors resulted in a fatality?

Fatalities

Please take a moment and tell us a few words about each error?

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In the month of [month], do you believe that you made a significant medical error, whether or not an adverse patient outcome occurred, other than due sleep deprivation or fatigue?

- Yes
 No

If you answered No to R1, skip to the next section

Approximately how many errors did you have in the month of [month]?

errors

How many, if any, errors resulted in an adverse patient outcome?

Adverse outcomes

If 0, skip this section

Please confirm you had ___ [fill in response from M2] error(s) that resulted in ___ [fill in response from M3] adverse patient outcome(s)?

- Yes, that is correct
 No, I will correct my answer to the previous questions.

If 0, skip this section

How many, if any, errors resulted in a fatality?

Fatalities

Please take a moment and tell us a few words about each error?
