Driving Performance of Residents after Six Consecutive Overnight Work Shifts

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ABSTRACT

Background: Residency training requires work in clinical settings for extended periods of time, resulting in altered sleep patterns, sleep deprivation, and potentially deleterious effects on safe performance of daily activities, including driving a motor vehicle.

Methods: Twenty-nine anesthesiology resident physicians in postgraduate year 2 to 4 drove for 55 min in the Virginia Driving Safety Laboratory using the Driver Guidance System (MBFARR, LLC, USA). Two driving simulator sessions were conducted, one experimental session immediately after the final shift of six consecutive night shifts and one control session at the beginning of a normal day shift (not after call). Both sessions were conducted at 8:00 AM. Psychomotor vigilance task testing was employed to evaluate reaction time and lapses in attention.

Results: After six consecutive night shifts, residents experienced significantly impaired control of all the driving variables including speed, lane position, throttle, and steering. They were also more likely to be involved in collisions. After six consecutive night shifts, residents had a significant increase in reaction times (281.1 *vs.* 298.5 ms; $P = 0.001$) and had a significant increase in the number of both minor (0.85 *vs.* 1.88; $P = 0.01$) and major lapses (0.00 *vs.* 0.31; $P = 0.008$) in attention.

Conclusions: Resident physicians have greater difficulty controlling speed and driving performance in the driving simulator after six consecutive night shifts. Reaction times are also increased with emphasis on increases in minor and major lapses in attention after six consecutive night shifts. (ANESTHESIOLOGY 2016; 124:1396-403)

THE Accreditation Council for Graduate Medical Education (ACGME) initiated duty hour limitations in 2003[1] and again in 2011[2] to promote high-quality learning and safe care. Despite these changes, residency training continues to require extended work in hospital and clinic settings, including overnight shifts. This results in altered sleep patterns, sleep deprivation, and potentially deleterious effects on the safe performance of daily activities. Before the initiation of duty hour restrictions in 2003, a survey of 2,734 interns determined that there was an increased likelihood of motor vehicle accidents and near-miss incidents after a single extended (approximately 32 h) work shift.[3] In that same time period before duty hour implementation, a single study of driving simulator performance among internal medicine residents and medical students after one night on call demonstrated impaired lane position variance and increased number of crashes.[4] Some studies in nonhealthcare professionals have evaluated the effects of acute sleep deprivation on performance in a driving simulator.[5–7] We sought to rigorously study the impact of six consecutive overnight work shifts on resident physician driving performance in a high-fidelity driving simulator,[8] rather than screen-based simulation employed in other studies.[9]

What We Already Know about This Topic

- Residency training requires work in clinical settings for extended periods of time, resulting in altered sleep patterns, sleep deprivation, and potentially deleterious effects on safe performance of daily activities.
- This study determined driving performance of residents after six consecutive overnight work shifts.

What This Article Tells Us That Is New

- Resident physicians have greater difficulty controlling speed and driving performance in the driving simulator after six consecutive night shifts. Reaction times are also increased with emphasis on increases in minor and major lapses in attention after six consecutive night shifts.

Sleep deprivation has neurobehavioral consequences and deleterious effects on cognitive functions such as vigilance, selective attention, orientation to sensory events, and attention to executive processing and tasks.[10,11] These effects are measurable through tests that focus on deterioration of

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attention such as psychomotor vigilance task (PVT) testing. PVT testing is highly sensitive to both acute and chronic sleep deprivation and measures reaction time to visual stimuli that occur at random intervals as well as lapses in attention.[12,13] As such, PVT testing has been used to demonstrate the effects of sleep loss from jet lag and shift work.[14] Indeed, PVT performance possesses implications for real-world risks, as deficits in sustained attention (lapses) and timely reactions adversely affect tasks in which response is critical, such as safe driving performance.[11]

We hypothesize that after six consecutive overnight work shifts, anesthesiology residents will have poorer driving performance as evidenced by impaired control of speed, lane position, throttle, and steering and will be involved in more collisions compared to their day shift work state. As concurrent validation of impairment, we further hypothesize that they will have impaired reaction time and more lapses on PVT testing when compared with their day shift work state.

Materials and Methods

After approval by the Institutional Review Board (University of Virginia Health System, Charlottesville, Virginia), anesthesiology residents on a prescheduled night float rotation at the University of Virginia were offered the opportunity to participate. From March 21, 2014 to February 11, 2015, 30 consecutive anesthesiology resident physicians gave written informed consent to participate in the study, and no residents declined participation. Two simulator sessions were conducted and both occurred at 8:00 AM, with the experimental session immediately after the final shift of six consecutive night shifts and one control session at the beginning of a normal day shift (not after call). A minimum of 10 days elapsed between the experimental and control sessions. This "night float" system is in compliance with current ACGME duty hour requirements, and there were no duty hour violations during the period of the study. At each evaluation session, residents provided information about their sleep habits and the use of any sleep aids during the previous week and completed an Epworth Sleepiness Scale (ESS) before and after each driving simulation session. For reference, the ESS is included (appendix 1) and requires respondents to rate their chance of dozing off to sleep in eight different situations, scored from 0 (never doze off) to 3 (high chance to doze off). ESS scores from 0 to 10 are considered normal, scores from 10 to 12 are borderline sleepiness and scores from 12 to 24 are abnormal, with high risk to doze. The ESS was employed as a validated, reproducible measure of resident sleepiness.[15]

Before each simulated driving experience, all residents underwent PVT testing. PVT is a 10-min computerized test that evaluates sustained attention and reaction time and measures lapses, both minor (less than 0.5 s) and major (0.5 to 1.0 s) in response, after randomly occurring visual stimuli.[16–18] After an opportunity to practice the PVT, residents sat in a quiet, well-lit room with a laptop on the desk in front of them and were instructed to push the space bar when the visual prompt appeared on the screen. PVT testing is independent of aptitude and learning effects, but reliable and sensitive to performance variation due to fatigue.[19]

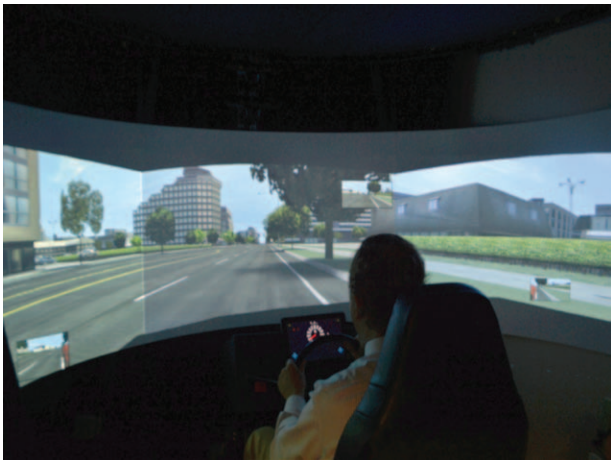

Fig. 1. Driver Guidance System: a high-fidelity immersive driving simulator.

The Driver Guidance System (fig. 1) is a high-fidelity immersive driving simulator made by MBFARR, LLC. Forward visuals are produced on a 210° curved screen by three projectors, along with virtual side and rear-view mirrors. The driving station has an adjustable seat, force feedback steering, digital dashboard, gear selector, brake, and gas pedals. A customized driving scenario was developed, utilizing an oval track with four lanes. The simulator room is controlled for light and sound.

Residents were seated and had time to familiarize themselves with the controls of the Driver Guidance System and were given instructions to drive the 2-mile, 4-lane oval track in the center of their current lane, to maintain speed at 45 mph, and to avoid obstacles when they appeared. The driving course was divided into four epochs, in order to investigate how quickly impaired driving could be detected: epoch 1 was 10 min of open road driving; epochs 2 to 4 were 15 min each of open road driving with nine randomly appearing obstacles. In total, residents drove for 55 min and were required to avoid collision with all obstacles. There was no other simulated traffic or distractions. We have previously demonstrated that high-fidelity driving simulation has high test–retest reliability ($r = 0.8$, $P < 0.001$) and robust internal consistency ($P < 0.001$) with minimal practice effect in multiple settings, including adults with diabetes mellitus, military personnel with history of traumatic brain injury, and young adults with attention deficit disorder and risky teenage behaviors as evaluated in a high-fidelity virtual driving simulator.[20–24]

Statistical Analysis

A power analysis was not conducted before enrolling resident physicians as this was a purely exploratory study. Based on our experience and our knowledge of resident night float clinical responsibilities, we aimed to enroll as many residents as possible. Five outcome variables in the driving simulator were measured, including speed, lane position, throttle, steering, and the number of collisions with obstacles (0 to 9). Steering and speed control are the most vulnerable measures of sleep deprivation. Since the resident interacted with the high-fidelity driving simulator only through turning of the steering wheel and control of the foot pedals, our performance variables were restricted to speed, steering, and collisions. A recent investigation has reported that poor speed control is a robust predictor of future collisions among novice drivers.[25] In the open road condition, 2 × 4 repeated measures ANOVA was conducted to evaluate the impact of day *versus* night shift performance on all of the variables. For the obstacle segments, 2 × 3 repeated measures ANOVA was conducted as the first epoch was removed, as it was entirely open road driving. Descriptive data from the ESS, sleepiness questionnaire, sleep habits log, and PVT testing data were collected and analyzed with the paired *t* test. Statistical software analysis was completed with IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., USA).

Results

Descriptive data from 29 residents are presented in table 1. One resident was consented for the study but was unable to complete the questionnaires, PVT, or driving simulation. In the night shift state, residents slept fewer hours daily in the previous week (6.6 ± 1.13 *vs.* 7.2 ± 0.74; P = 0.002) as well as in the 24 h before the driving simulation (6.3 ± 1.46 *vs.* 7.2 ± 1.1; P = 0.025). In the night shift state, residents also had significantly increased sleepiness scale scores (ESS night shift predrive score 10.2 ± 4.99 *vs.* day shift predrive score 6.4 ± 3.84; P < 0.001 and ESS night shift postdrive score 12.3 ± 5.66 *vs.* day shift postdrive score 7.3 ± 3.9; P < 0.001). On the sleepiness questionnaire (appendix 2), residents reported feeling less alert and less safe to drive in the night shift as compared to the day shift state.

Data from 26 of the 29 residents were suitable for driving simulator analysis. Data from three residents were lost after a hard drive failure and could not be analyzed. Figure 2 and table 2 display driving performance in the open road condition. Residents in the night shift work state had difficulty in controlling speed (P < 0.001), lane position (P = 0.03), throttle (P < 0.001), and steering (P = 0.01) compared to day shift condition. Figure 3 and table 3 illustrate driving performance in the obstacle segments during 2 s before and 6 s after the appearance of an obstacle. In order to avoid a collision, residents in the night shift state had greater mean deviation in speed (P = 0.04) and throttle (P = 0.04), whereas steering (P = 0.73) and lane position (P = 0.80) were not significantly different compared to their day shift work condition. Residents in the night shift work state also had increased number of collisions compared to day shift residents (epoch 2: 0.75 *vs.* 0.3; epoch 3: 0.45 *vs.* 0.23; and epoch 4: 0.30 *vs.* 0.15; P = 0.010).

Table 1. Descriptive Data

Age (average, yr)	29.8				
PGY level	1	2	3	4	
(n)	0	16	5	8	
Sex female: male (n)	6	23			
	Day Shift	Night Shift			
Use of sleep aids (n)	4	2			
Use of caffeine (n)	8	1			
Variable*	Control (Mean ± SD)	Experimental (Mean ± SD)	*df*	*t*	Significance (*P* Value)
Average hours slept daily for last 6 days	7.2 ± 0.74	6.6 ± 1.13	25	3.53	0.002
Average hours slept last 24 h	7.2 ± 1.1	6.3 ± 1.46	26	2.37	0.025
Epworth Sleepiness Scale (appendix 1)					
Predrive	6.4 ± 3.84	10.2 ± 4.99	26	–4.69	< 0.001
Postdrive	7.3 ± 3.9	12.3 ± 5.66	26	–5.95	< 0.001
Sleepiness questionnaire (appendix 2)					
1. How safe are you to drive now?					
Predrive (%)	97.8 ± 3.76	84.2 ± 15.46	26	5.51	< 0.001
Postdrive (%)	92.6 ± 8.63	68.3 ± 27.84	26	5.18	< 0.001
2. How alert are you now?					
Predrive (%)	91.0 ± 7.93	75.6 ± 17.81	26	4.72	< 0.001
Postdrive (%)	87.6 ± 12.66	64.4 ± 24.74	26	4.94	< 0.001
3. How sleepy are you now?					
Predrive (%)	14.4 ± 12.43	44.4 ± 22.16	26	–7.33	< 0.001
Postdrive (%)	26.5 ± 26.12	56.5 ± 26.56	26	–4.06	< 0.001

*All variables were statistically evaluated using the paired samples *t* test.

df = degrees of freedom; PGY = postgraduate year.

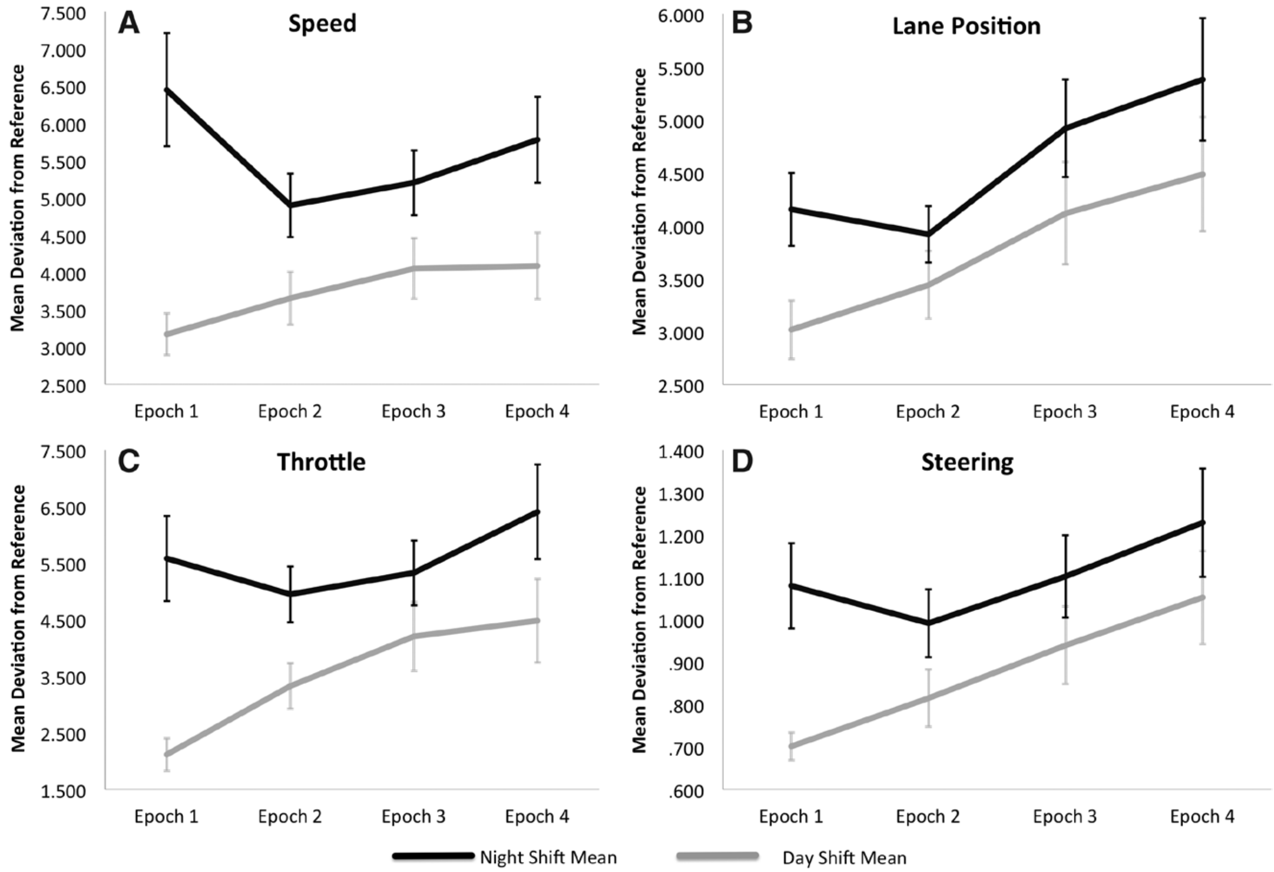

Fig. 2. Driving variables in the open road: (*A*) speed (*P* < 0.001); (*B*) lane position (*P* = 0.03); (*C*) throttle (*P* < 0.001); and (*D*) steering (*P* = 0.01). For speed, deviation from reference is the difference between subject speed and the goal of 45 miles per hour; for lane position, deviation from reference is the distance from the center of the lane; for throttle, deviation from reference is the position of pedal location; and for steering, deviation from reference is the position of the steering wheel from neutral or straight ahead.

Table 2. Driving Performance in the Open Road

			Control		Night Shift	
Variable	*F*	*P* Value	Mean	SEM	Mean	SEM
Throttle						
Condition	24.02	< 0.001	3.49	0.34	5.67	0.52
Epoch	6.46	< 0.001				
Speed						
Condition	19.98	< 0.001	3.8	0.27	5.72	0.42
Epoch	2.35	0.12				
Steering						
Condition	8.18	0.01	0.87	0.06	1.09	0.08
Epoch	8.04	< 0.001				
Position						
Condition	5.72	0.03	3.72	0.32	4.55	0.34
Epoch	11.35	< 0.001				

Twenty-six residents' PVT data were analyzed for comparison of mean reaction time as well as the number of major and minor lapses in the night shift *versus* day shift states. Day shift and night shift conditions differed in PVT in reaction times (281.1 ± 33.1 ms *vs.* 298.5 ± 32.1 ms; *P* = 0.001), minor lapses less than 0.5 s (0.85 ± 1.32 *vs.* 1.88 ± 2.18; *P* = 0.01), and major lapses greater than 0.5 s (0.00 ± 0 *vs.* 0.31 ± 0.55; *P* = 0.008).

Discussion

After six consecutive overnight work shifts, anesthesiology residents have impaired driving performance in a high-fidelity driving simulator. Even in the open road without any obstacles to avoid, residents experienced significantly impaired control of all the driving variables including speed, lane position, throttle, and steering (fig. 2) after six consecutive night shifts. While residents in the night shift condition seemed to have consistently poor control of speed and lane position, especially at the beginning of their driving, residents in the day shift condition initially started out with better control but experienced degradation of control of speed and lane position over time. We speculate that this may represent boredom or task fatigue over the course of performing a monotonous activity. Indeed, informal comments from residents support this hypothesis. Figure 3 displays similar impairment of resident driving performance, with residents in the night shift condition swerving to avoid collision with each obstacle.

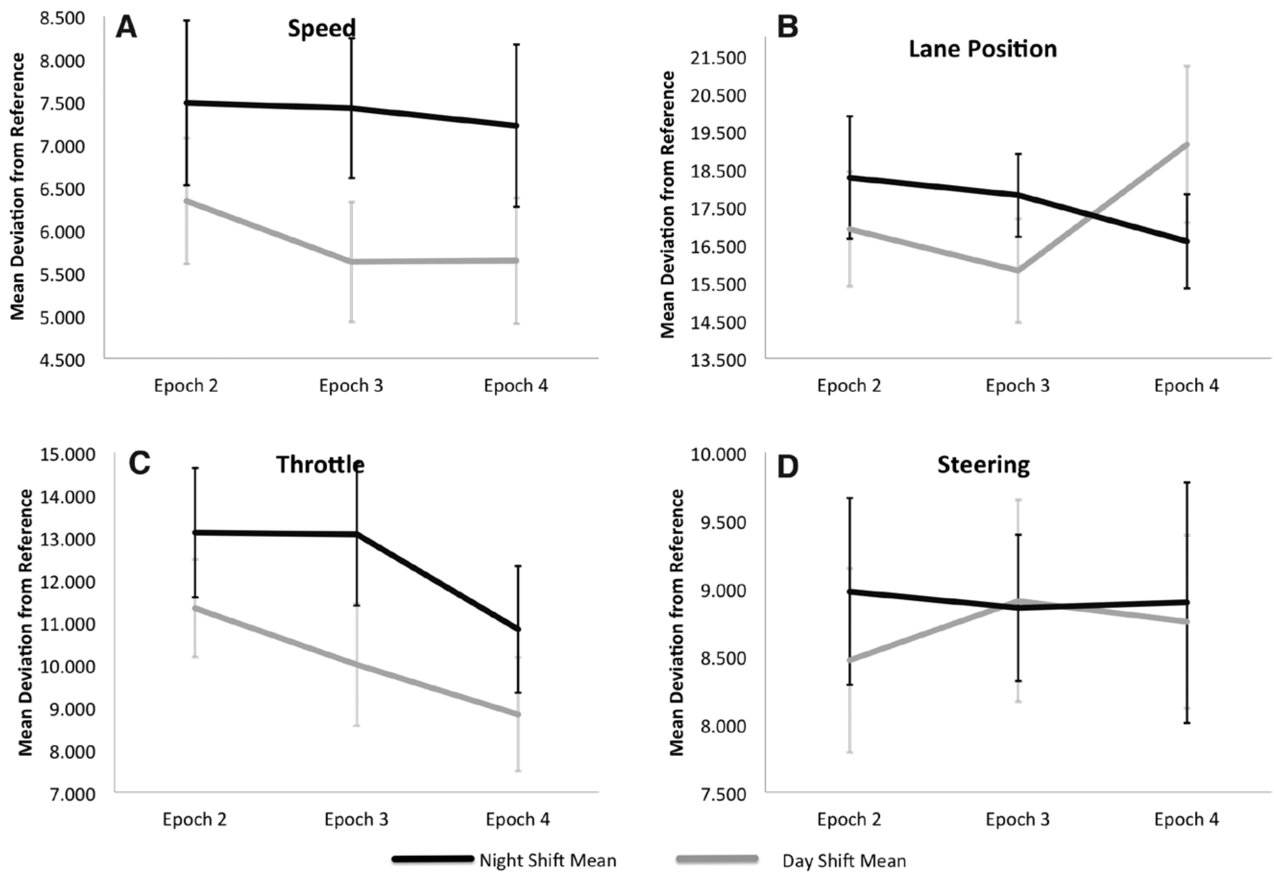

Fig. 3. Driving variables around the obstacles: (*A*) speed (*P* = 0.04); (*B*) lane position (*P* = 0.8); (*C*) throttle (*P* = 0.04); and (*D*) steering (*P* = 0.73). For speed, deviation from reference is the difference between subject speed and the goal of 45 miles per hour; for lane position, deviation from reference is the distance from the center of the lane; for throttle, deviation from reference is the position of pedal location; and for steering, deviation from reference is the position of the steering wheel from neutral or straight ahead.

Table 3. Driving Performance around the Obstacles

			Control		Night Shift	
Variable	*F*	*P* Value	Mean	SEM	Mean	SEM
Throttle						
Condition	4.81	0.04	10.06	1.14	12.34	1.35
Epoch	3.81	0.03				
Speed						
Condition	4.73	0.04	5.87	0.63	7.38	0.65
Epoch	0.32	0.73				
Steering						
Condition	0.13	0.73	8.71	0.59	8.91	0.59
Epoch	0.05	0.95				
Position						
Condition	0.07	0.8	17.3	1.3	17.56	0.98
Epoch	0.43	0.65				

On PVT testing, there was a small but significant difference (17 ms) in reaction times between the day shift and night shift conditions. A change in reaction time of 17 ms, while statistically significant, is unlikely to be relevant or clinically important in the real world. Most importantly, we found significant differences *via* the PVT in the number of minor (0.2 to 0.5 s) and major (greater than 0.5 s) lapses. We believe that the increased number of lapses in the night shift condition is much more important than the change in mean reaction time because it is these lapses in attention that may lead to collisions and accidents.

Although driving simulator performance may be more sensitive to the effects of fatigue compared to real road driving, high-fidelity driving simulators are considered to be a valid measure of driving performance.[26] Using a high-fidelity driving simulator, internal medicine residents and medical students demonstrated increased lane position variability and increased number of crashes after a single night on call.[4] Using a single-monitor computer simulator, a study in pediatric residents revealed poor driving performance after overnight call during a "heavy-call" (every fourth or fifth night) rotation.[9]

Before the implementation of resident duty hour restrictions in 2003, Barger *et al.*[3] demonstrated that there was an increased likelihood of motor vehicle accidents and near-miss incidents after an extended work shift (mean duration of 32 h). Using a screen-based (nonimmersive) simulator, Arnedt *et al.*[9] found that the postcall performance driving impairment during a heavy call rotation was comparable to the level of impairment associated with 0.04 to 0.05 g% blood alcohol. Although the degree to which simulator results can be transferred to real road driving is unknown, our results suggest that driving performance is impaired even after a 14-h night shift, consistent with the most current ACGME duty hour standards. Indeed, night shift residents in this study slept 6.33 h on average in the 24 h before the driving experiment. These results suggest that changing from a traditional call system to a night-float or night shift system does not protect residents from the impact of fatigue on driving performance, even though it may allow residents more sleep during the day.

Our evaluation of driving performance in a simulator after night shift is not without limitations. One limitation is that residents were always enrolled in the study as they began their night shift week and thus the night shift condition was always evaluated before the control, day shift state. This may cause either the early epochs of the night shift sessions to appear worse or the day shift sessions to be artificially improved due to a possible "simulator learning" effect. We believe that the potential impact of any "simulator learning" effect is minimal as driving is not a new skill to all the residents in the study, and other studies our group conducted using high-fidelity driving simulation have not demonstrated a learning effect.[8,20–24] Indeed, we have previously demonstrated that high-fidelity driving simulation has high test–retest reliability (r = 0.8, P < 0.001) with robust internal consistency (P < 0.01) on five operational tests with no significant learning effect noted with mean change of 0.86 and 1.35 points on operational and tactical driving quotients (operational tests: visual, motor, and cognitive abilities required for safe operation of motor vehicle; tactical tests: steering, braking, speed control, and judgment variables), respectively.[8,20–24] Finally, the applicability of any study conducted in a simulator—even high-fidelity immersive simulation—to real-life driving is unknown.

Night work is an unavoidable aspect of medicine. Anesthesiology residency programs limit night float work in order to regulate duty hours and to provide time for adequate resident rest. Unfortunately, there is a paucity of information regarding the optimal duration of night float work and the impact of various "call" strategies on resident well-being. The goal of future investigations will be focused on answering these critically important questions. As a specialty, we must endeavor to train the next generation of physician anesthesiologists to be the best possible clinicians and scientists; however, we must also craft our training to maximize the personal well-being and safety of our trainees. We call upon other investigators to help us answer these important questions.

Conclusions

Residents have greater difficulty controlling speed and other measures of driving performance in the driving simulator, including obstacle collisions, after six consecutive overnight work shifts. In addition, reaction times are increased with more major and minor lapses of attention.

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Competing Interests

The authors declare no competing interests.

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Appendix 1. Epworth Sleepiness Scale

Date: ________
Your age: (yr) ________Your sex: ___________

How likely are you to doze off or fall asleep in the situations described below, in contrast to feeling just tired?

This refers to your usual way of life in recent times.

Even if you haven't done some of these things recently, try to work out how they would have affected you.

Use the following scale to choose the *most appropriate number* for each situation:

0 = Would *never* doze
1 = *Slight* chance of dozing
2 = *Moderate* chance of dozing
3 = *High* chance of dozing

Situation	Chance of dozing
Sitting and reading	_________
Watching TV	_________
Sitting, inactive in a public place (*e.g.*, a theatre or a meeting)	_________
As a passenger in a car for an hour without a break	_________
Lying down to rest in the afternoon when circumstances permit	_________
Sitting and talking to someone	_________
Sitting quietly after a lunch without alcohol	_________
In a car, while stopped for a few minutes in the traffic	_________
Total	_________

Appendix 2. Sleepiness and Driving Questionnaire

Participant # ______ Date: ________ Time: ________ Trial: Control
Exp.

Predrive

Give a percentage that reflects your current situation:

How *Safely* can you drive a car right now

____

0% Not at all Safely	100% Completely Safely

How *Alert* are you right now

____

0% Not at all Alert	100% Completely Alert

How *Sleepy* are you right now

____

0% Not at all Sleepy	100% Cannot keep eyes open

Postdrive

Give a percentage that reflects your current situation:

How *Safely* can you drive a car right now

____

0% Not at all Safely	100% Completely Safely

How *Alert* are you right now

____

0% Not at all Alert	100% Completely Alert

How *Sleepy* are you right now

____

0% Not at all Sleepy	100% Cannot keep eyes open