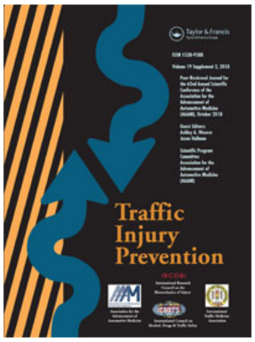

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The effect of poor sleep and occupational demands on driving safety in medical residents

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any vehicle they would be purchasing in the future as the features become more prevalent.

Discussion

This exploratory research yielded important and novel viewpoints from end-users of ADAS. The findings are an important first step to help determine driver characteristics and individual factors that influence perceptions, behaviors, and interactions with safety technology. This work also helps identify future research needs, and future studies should include larger and more representative samples in order to extend conclusions to the general public and to examine other factors such as age and driving experience (e.g., McBride et al. 2011) and technology acceptance. Though the findings from this current research include the views of only a small number of users, they can be used to develop survey instruments to be administered broadly to larger samples. Insights gathered in this study illustrate the challenges and opportunities facing manufacturers, suppliers, technology providers, and safety researchers. The dynamic interaction between safety systems and the human driver is at the crux of driving performance and safety. Without understanding human behavior, expectations, and perceptions, it is impossible to design a system that can be easily used by human (Merat and Lee 2012). More attention should be paid to the human factor issues related to automated vehicle technologies. With this knowledge, industry can be bolstered by additional information to design for, which can improve multiple aspects of the driver–vehicle–environment relationship. By thoroughly exploring many of these issues through in-depth discussions with consumers, this research and related future work can help generate important foundational evidence that can inform various aspects of vehicle safety technologies, including design, training, awareness, and raising trust, all leading toward knowledge that can contribute toward effective deployment and maximization of safety benefits of these systems.

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The effect of poor sleep and occupational demands on driving safety in medical residents

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ABSTRACT

Objective: The Accreditation Council for Graduate Medical Examination recently revised and implemented duty hour standards that increased maximum duty hours for first-year medical residents and reduced the minimal amount of time off between duty periods for all medical residents.

KEYWORDS
Drowsy driving; driving safety; occupational demands; sleep; fatigue; stress

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Little work has examined driving performance of medical residents at multiple periods surrounding duty, including in reference to off-duty driving performance as a baseline. Certain work-related factors that may be negatively impacted in medical residents, such as sleep quality, fatigue, and stress, are known to affect mental and physical performance and may further exacerbate driving risks. The overall objective of this study was to examine driving performance of medical residents off duty, preduty, and postduty using a high-fidelity driving simulator.

Method: Thirty-two medical residents were enrolled and wore sleep tracking devices over several days. Both self-reported and objective estimates of sleep quality, fatigue, and stress were collected at off-duty, preduty, and postduty points of time. The medical residents drove in a high-fidelity driving simulator at each time point to provide objective driving performance metrics.

Results: Findings indicated that medical residents experienced the highest levels of stress and sleep propensity preduty and displayed riskier driving behaviors postduty. Those further into their residency were less affected by the negative effect of stress on driving performance, and those with better sleep quality metrics were also less affected by the negative effects of increased stress on driving outcomes.

Conclusions: The impact of occupational demands on psychophysiological outcomes requires further investigation to better understand the mechanisms of how work demands affect these psychophysiological outcomes. Understanding how to mitigate high job strain may have several implications in improving psychophysiological functions impacted by occupational demands, namely, sleep quality and stress, and subsequently improving driving safety outcomes that may also be negatively affected by the duty demands.

Introduction

The Accreditation Council for Graduate Medical Examination (2017) recently revised and implemented duty hour standards that increased maximum duty hours for first-year medical residents and reduced the minimal amount of time off between duty periods for all medical residents. The new standards were introduced largely without consideration of empirical research on objectively measured occupational health and safety factors for medical residents, particularly in contexts where their safety may be at risk, such as driving. Little work has examined driving performance of medical residents at multiple periods surrounding duty, including in reference to off-duty driving performance as a baseline. Certain work-related factors such as sleep quality, fatigue, and stress are known to affect mental and physical performance (Gharagozlou et al. 2015; Jackson et al. 2013; Wickens et al. 2013) and may further exacerbate driving risks. The overall objective of this study was to examine driving performance in medical residents off duty, preduty and postduty using a high-fidelity driving simulator.

Method

Thirty-two medical residents ($M_{\text{age}} = 28.56$ years, SD = 2.18) wore actigraphy watches continuously over the study period ($M = 8.47$ days, SD = 3.04) that provided objective estimates of sleep duration and sleep quality. The actigraphy watches were calibrated to each participant's age, gender, height, and weight and contained a 3-axis accelerometer to estimate movement and sleep continuously (Welk et al. 2004). During the study period, the medical residents completed 3 appointments: (1) Off day; (2) preduty; and (3) postduty. The pre- and postduty driving appointments occurred on the same day, with the duty shift occurring between them. The order of the off-day and on-day was randomized. At each appointment, the medical residents provided salivary cortisol, a well-validated biomarker of stress measurement (Dickerson and Kemeny 2004; Gaab et al. 2005), where higher cortisol levels indicated higher stress (Walker et al. 2011), and drove in a state-of-the-art driving simulator, shown in Figure 1. The simulated driving scenario was a 16-min nighttime drive with a scenario resembling the local region. Each of the 3 drives contained a hazard requiring a response by the driver to avoid a collision.

Results

Fixed effects linear regressions adjusted for repeated observations within each participant indicated that medical residents displayed riskier driving behaviors postduty as indicated by significantly faster average driving speed postduty, $F(2,60) = 14.02$, $P = .001$, compared to both preduty, $t(60) = 5.10$, Tukey-adjusted $P = .01$, and off day, $t(60) = 3.78$, Tukey-adjusted $P = .003$, time points (see Table 1). Logistic regressions indicated that the odds of obtaining less than the amount of sleep associated with safe driving outcomes (7 h) was 325% higher on nights preceding a workday compared to the nights preceding an off day, $\chi^2(1) = 4.73$, $P = 0.03$ (odds ratio = 4.25; 95% confidence interval, 1.15–15.65). Actigraphy-estimated sleep variables

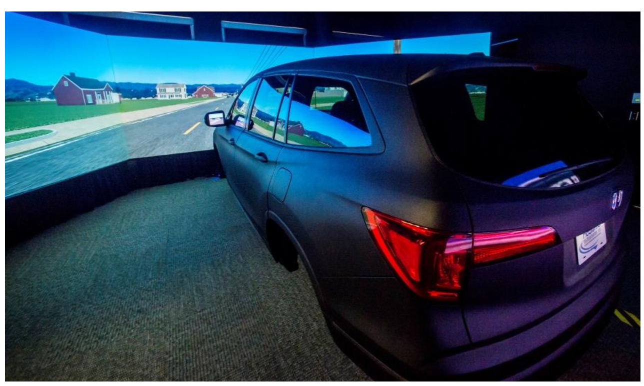

Figure 1. Realtime Technologies, Inc., driving simulator utilized in the study.

Table 1. Simulated driving performance variables at off-day, preshift, and postshift duty periods.[a]

	Duty period									
	Off day			Workday						
				Pre			Post			
Driving variable	Mean (SD)	*n*	Range	Mean (SD)	*n*	Range	Mean (SD)	*n*	Range	*F* or χ^2
Average Speed	**52.14**^{1} (5.02)		38.13–64.19	**51.38**^{1} (4.38)		41.61–58.23	**54.86**^{2} (4.64)		43.28–63.67	**14.02**
Speed variability	23.25 (2.45)		18.11–29.25	23.21 (2.55)		18.77–31.03	22.76 (2.52)		16.56–28.19	0.81
Standard deviation of lane position	1.19 (0.14)		0.92–1.49	1.21 (0.19)		0.90–1.87	1.22 (0.20)		0.91–1.83	0.44
Braking reaction time	0.49 (0.19)		0.08–0.98	0.59 (0.14)		0.25–0.90	0.57 (0.20)		0.28–1.15	2.29
Total collisions	—	1	—		3	—	—	5	—	2.80

[a]Bold indicates significant difference among the time points ($P < .05$). Superscript numbers indicate significant unique Tukey-Kramer-adjusted differences between noted time point means.

Table 2. Descriptive statistics for actigraphy-estimated sleep during participation.[a]

Variable	Mean (SD)	Range
Sleep periods	5.88 (2.88)	2.0–13.0
Duration (h)	7.82 (1.77)	4.38–13.77
Sleep variation (h)	2.92 (1.42)	0.48–5.56
Efficiency (%)	92.08 (3.76)	77.90–96.60
WASO (min)	37.97 (14.57)	16.43–75.09
SFI (%)	31.87 (11.57)	11.81–64.01
Lowest duration in 24-h period (h)	4.88 (1.80)	2.17–9.70

[a]WASO = wake after sleep onset; SFI = sleep fragmentation index.

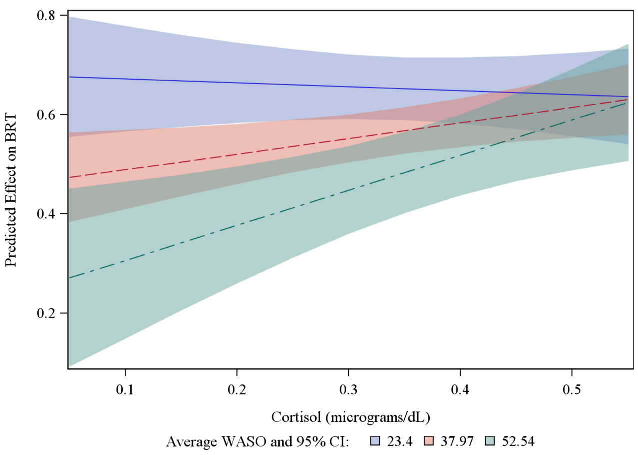

Figure 2. Interaction of the average wake after sleep onset (WASO) measure of sleep quality with stress (cortisol) on braking reaction time (BRT). Higher stress (increased cortisol) was associated with increased reaction times only at the average (red) and highest (green) WASO values.

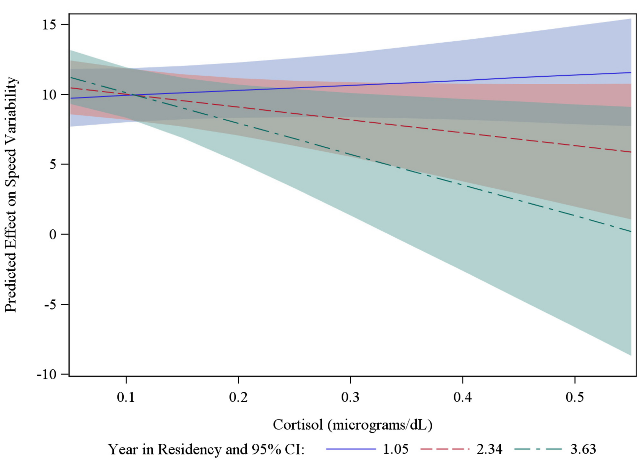

Figure 3. Interaction of postduty stress (cortisol) with year in residency program on postduty speed variability.

averaged across participation are displayed in Table 2. Driving performance was also affected by stress, and this effect differed as a function of sleep quality, such that the medical residents displayed slower braking reaction times at higher levels of stress but only at poorer levels of average sleep quality, $F(1,22) = 5.69$, $P = .03$. See Figure 2 for a display of simple slopes of the stress by average sleep quality interaction. Additionally, medical residents further into their residency were less affected by the negative effect of stress on speed variability compared to their less experienced peers, $F(1,26) = 6.40$, $P = .02$, as displayed in Figure 3.

Discussion

The impact of occupational demands on psychophysiological outcomes requires further investigation to better understand how the demands subsequently affect driving safety. Medical residents display high levels of stress and poor sleep outcomes throughout medical residency (Lebares et al. 2018; Zebrowski et al. 2018), and their driving safety may be degraded as a result. This study was among the first to compare pre- and postduty driving performance to an off day as well as utilize objectively estimated measures of sleep and stress to understand how these psychophysiological factors are affected by occupational demands. Understanding how to mitigate high job strain may have several implications for sleep quality and stress and subsequently improving driving safety outcomes that may also be negatively affected by the duty demands. Improving sleep quantity and quality in medical residents may mitigate the high job strain shown in residency (Lebares et al. 2018) and subsequently improve driving outcomes. These findings may further develop work demand models and identify both temporary situations, such as immediately postduty, and long-term occupational contexts where driving safety may be affected as a result of occupational demands.

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Evaluating the response of the PIPER scalable human body model across child restraining seats in simulated frontal crashes

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ABSTRACT

Objective: Booster seats ensure appropriate belt fit for children that a traditional vehicle seat belt cannot offer to small occupants. In this study, the responses of the PIPER 6-year-old human body model are compared to the traditional Q6 anthropomorphic test dummy (ATD).

Methods: Eight frontal impact finite element simulations were run using 4 different child restraining systems on the FMVSS 213 test bench. Kinematics and kinetics were extracted and compared between the 2 child models.

Results: The PIPER 6-year-old showed variation by 11.2 ± 14.1% (head resultant acceleration, *G*), 20.4 ± 50.3% (chest resultant acceleration, *G*), 272.9 ± 188.4% (chest displacement, mm), 24.8 ± 17.5% (maximum head excursion, mm), −31.5 ± 5.1% (neck force, F_z, N), −73.8 ± 2.8% (neck moment, M_y, N.m), and −60.4 ± 7.2% (N_{ij}) compared to the Q6. However, the kinematics of both models were nearly similar.

Conclusions: The PIPER model has a flexible neck and shows higher chest displacement compared to the Q6. We hypothesize that this is due to the inherent anatomical and mechanical differences between the human body model and the ATD model. More research is needed to explore these differences systematically.

KEYWORDS
PIPER; Q6; human body model; finite element; child occupant safety; FMVSS 213

Introduction

There are primarily 3 types of booster seats available in the U.S. market today—namely, high-back, low-back, or backless boosters—and a newer type of child restraint seat (CRS), heightless CRSs. The PIPER scalable child human body

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