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ORIGINAL ARTICLE

Brief (<4 hr) sleep episodes are insufficient for restoring performance in first-year resident physicians working overnight extended-duration work shifts

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Abstract

Study Objectives: The Accreditation Council for Graduate Medical Education (ACGME) recently reinstated extended-duration (24–28 hr) work shifts (EDWS) for postgraduate year 1 (PGY-1) resident physicians. This study examined the relationship between overnight sleep duration during EDWS and subsequent "post-call" performance in PGY-1 resident physicians.

Methods: Thirty-four PGY-1 resident physicians (23 males; 24–32 years) were studied between 2002 and 2004 during 3-week Q3 "on-call" rotation schedules in the Medical and Cardiac Intensive Care Units at Brigham and Women's Hospital in Boston. Daily sleep logs (validated by ambulatory polysomnography) were collected and the 10 min psychomotor vigilance task (PVT) was administered every ~6 hr during each EDWS. Generalized estimating equations were used to examine the relationship between overnight sleep duration and PVT performance "post-call" (0500–1900 hr). Postcall performance during EDWS was compared with sessions matched for time-of-day and weeks-into-schedule in the same resident physician during an intervention schedule that eliminated EDWS.

Results: Resident physicians obtained an average of 1.6 ± 1.5 hr cumulative sleep overnight during EDWS (<4 hr on 92% of nights). PVT attentional failures were significantly reduced only after >4 hr sleep ($p = 0.027$ versus no sleep). Despite this apparent improvement, the odds of incurring >1 attentional failure were 2.72 times higher during postcall following >4 hr sleep compared with matched sessions during non-EDWS.

Conclusions: Even with >4 hr sleep overnight (8% of EDWS), performance remained significantly impaired. These findings suggest that even "strategic napping," a recommendation recently removed from ACGME guidelines, is insufficient to mitigate severe performance impairment introduced by extending duty beyond 16 hr.

Statement of Significance

The present study examined the amount of overnight spontaneous sleep that postgraduate year 1 resident physicians obtained during extended-duration work shifts and its impact on next-day performance. Resident physicians obtained less than 4 hr of spontaneous overnight sleep on 92% of extended-duration work shifts, an amount insufficient to prevent serious neurobehavioral performance impairment. Even resident physicians who obtained more than 4 hr of sleep overnight during extended-duration work shifts remained significantly impaired compared with their performance during an intervention schedule with no extended-duration work shifts. These findings have important implications for the development of public policies related to the health and safety of resident physicians and their patients.

Key words: sleep deprivation; resident physicians; patient care; medical errors; medical training

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Introduction

The Accreditation Council for Graduate Medical Education (ACGME) in the United States recently increased the permitted shift duration for postgraduate year 1 (PGY-1) resident physicians, reinstating extended-duration (24–28 hr) work shifts (EDWS) [1]. These changes were made in part due to a recent cluster-randomized noninferiority trial that reported noninferior patient outcomes and no significant difference in resident well-being and quality of educational training between resident physicians in programs subject to the then-standard work policy (≤16 hr for PGY 1 resident physicians, ≤28 hr for PGY 2–5 resident physicians) and those who adhered to a flexible policy that included EDWS [2], despite previous findings to the contrary [3]. In addition, without explanation, the ACGME removed their prior recommendation for strategic napping during EDWS, the intent of which was to mitigate the negative impact of long continuous duty hours on performance. Given the recent increase in permitted shift duration, we revisited existing data from resident physicians studied under the recently reinstated traditional Q3 schedule to examine the amount of spontaneous sleep obtained overnight during EDWS and its subsequent impact on postcall performance [4].

Methods

The original study was approved by the human research committee of Partners Healthcare and Brigham and Women's Hospital (2001P000814), and all participants provided written informed consent. Thirty-four PGY-1 resident physicians (23 males; mean ± standard deviation 28.0 ± 1.83 years old) were studied for 3 weeks on a Q3 schedule (24–30 hr on-call EDWS every other shift, as previously described) between 2002 and 2004 [5]. Residents completed daily sleep and work logs (validated by ambulatory polysomnography 3–4 days per week) [4] and performed a 10 min psychomotor vigilance task (PVT) every ~6 hr during each EDWS [5]. Here we examined PVT attentional failures (count of reaction times > 500 ms, normalized by the Freeman–Tukey transform $\sqrt{n}+\sqrt{n+1}$) from 295 sessions collected during the second day of each EDWS (500–1900 hr, "post-call") relative to the overnight (2300–700 hr) cumulative spontaneous sleep duration (binned into 0, >0–1, >1–2, >2–3, >3–4, and >4 hr; Table 1) during the EDWS using a generalized estimating equation (PROC GENMOD, SAS 9.3, Cary, NC). Time of day of PVT administration (early postcall: 500–830 hr versus late postcall: 1000–1900 hr) and study week (week 1, EDWS blocks 1–2; week 2, EDWS blocks 3–4; and week 3, EDWS blocks 5–6) were included as covariates to control for circadian phase and chronic sleep restriction, respectively. $p < 0.05$ was considered statistically significant.

Results

In 202 EDWS included in our analysis, PGY-1 resident physicians obtained 1.6 ± 1.5 hr (mean ± standard deviation) of sleep overnight; total sleep time overnight was <4 hr on 92% of nights. Across 295 PVT sessions, attentional failures were significantly reduced ($p = 0.027$) following >4 hr of sleep only (all bins referenced to 0 hr of sleep, Figure 1). Attentional failures were higher in study weeks 2 and 3 ($p = 0.0008$ and $p = 0.0006$, respectively, referenced to study week 1), as observed previously [5], but no interaction between sleep duration and study week on attentional failures was observed. No significant effect of test time postcall (early postcall versus late postcall) was observed.

Obtaining >4 hr of sleep overnight during EDWS provides only partial recovery. Although more than 10 attentional failures were observed in only 7% of PVT sessions following >4 hr of sleep overnight (compared with 23% following 0–4 hr of sleep), more than 1 attentional failure was observed in 68% of sessions following >4 hr of sleep (Figure 2). To further examine the impact of EDWS on postcall performance, we compared these 295 PVT sessions with PVT sessions matched for time of day and study week in the same resident physicians during an intervention schedule, which eliminated EDWS, limited continuous duty to no longer than 16 hr per work shift, and allowed resident physicians to sleep at home [4, 6]. Overnight sleep duration prior to these matched PVT sessions was 6.92 ± 1.37 hr (range 3.92–12.77 hr). The odds of incurring more than 1 attentional failure (the median number of attentional failures observed during the non-EDWS sessions) was 2.40 times higher (95% CI: 1.72–3.34) overall (i.e. across all spontaneous overnight sleep durations) on postcall PVT sessions compared with matched sessions completed during non-EDWS, and 2.72 times higher (95% CI: 1.19–6.20) among PGY-1 resident physicians who obtained >4 hr of spontaneous sleep overnight during EDWS (Table 1).

Discussion

More than 4 hr of actual sleep was required to decrease significantly the number of attentional failures observed during

Table 1. Odds ratio (95% CI) of attentional failures in PGY-1 resident physicians during Q3 compared with sessions matched for resident, time of day, and time into study during the intervention schedule

PVT (N)[†]	Sleep range (hr)	Sleep duration (mean ± *SD*)	Lapses (mean ± *SD*)	Odds ratio (95% CI)		
				>1 lapse[‡]	>5 lapses	>10 lapses
81 (24)	0.00–0.00	0.00 ± 0.00	8.10 ± 9.56	3.92 (2.25, 6.84)	2.80 (1.69, 4.63)	3.38 (1.84, 6.21)
45 (19)	0.05–1.00	0.74 ± 0.27	6.73 ± 8.67	1.47 (0.78, 2.76)	1.73 (0.91, 3.31)	3.46 (1.64, 7.28)
64 (24)	1.08–2.00	1.60 ± 0.24	5.83 ± 7.79	2.14 (1.23, 3.74)	2.02 (1.16, 3.52)	1.58 (0.73, 3.41)
46 (19)	2.03–3.00	2.53 ± 0.29	6.24 ± 7.92	2.00 (1.06, 3.78)	1.83 (0.96, 3.47)	3.01 (1.41, 6.40)
31 (13)	3.02–3.96	3.43 ± 0.23	10.29 ± 11.23	2.34 (1.08, 5.06)	3.60 (1.69, 7.67)	6.15 (2.75, 13.75)
28 (10)	4.15–6.33	5.04 ± 0.66	4.79 ± 5.31	2.72 (1.19, 6.20)	1.68 (0.76, 3.74)	1.42 (0.46, 4.36)

[†]PVT indicates the number of psychomotor vigilance task sessions included in each sleep bin; *N* indicates the number of resident physicians represented by those PVT sessions.

[‡]Attentional failure (lapse) cutoffs are based on the median (1 lapse), 75th percentile (5 lapses), and 90th percentile (10 lapses) of all matched sessions during the intervention.

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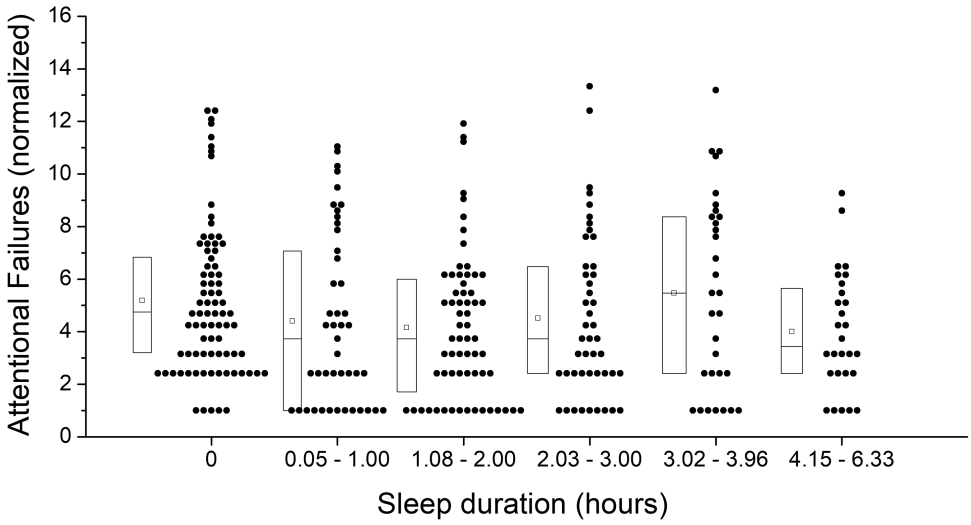

Figure 1. Attentional failures (number of lapses, normalized by $\sqrt{n}+\sqrt{n+1}$) from all 295 sessions of the PVT included in the current analysis are plotted by sleep duration bin. Individual points within a bin have been offset to show overlapping points. The median and interquartile range (boxplots) and mean (open squares) also are plotted for each sleep duration bin.

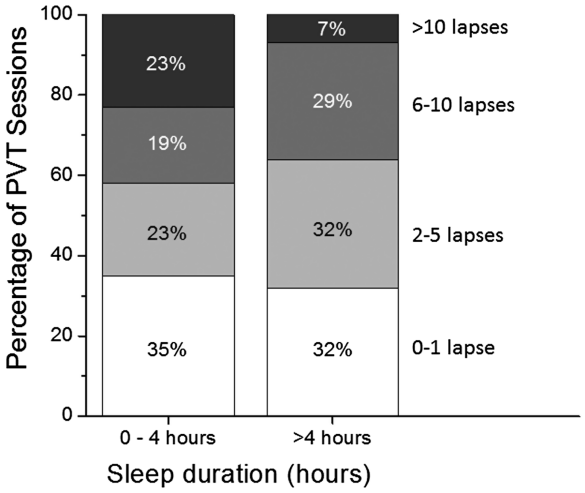

Figure 2. Stacked bar chart comparing the percentage of PVT sessions following 0–4 hr of spontaneous sleep and >4 hr of sleep in which the number of attentional failures fell between the designated thresholds among PGY-1 resident physicians. White bars: at or below 1 lapses; light gray bars: between 2 and 5 lapses; dark gray bars: between 6 and 10 lapses; black bars: >10 lapses.

the second half of an EDWS ("post-call") when compared with performance following no sleep overnight among PGY-1 resident physicians. Sleeping 4 or fewer hours overnight yielded no significant improvement on any performance measure compared with zero sleep. PGY-1 resident physicians in this study were not provided with protected time for sleep during EDWS. In practice, it is unusual for resident physicians to obtain more than 4 hr of sleep overnight; in our data set, it only occurred in 8% of the EDWS analyzed. In 92% of the EDWS analyzed, resident physicians obtained 4 or fewer hours of total sleep time overnight, including 28% during which no sleep was obtained. Two previous studies of protected sleep time during EDWS have reported only moderate increases in overnight sleep duration compared with no protected time (average increase of 0.43 to 1.00 hr), and in no cases was the average sleep duration more than 4 hr (2.33 to 3.04 hr sleep) [7, 8]. Furthermore, at least one study has reported that 4 hr of protected sleep time led to a slight reduction (of 0.20 hr) in sleep duration [9]. Taken together, these data suggest a net benefit of approximately 10 more min of sleep for each hour of protected time, a proportion much lower than when work hours are reduced to increase resident sleep, where nearly a third (30%) of the extra time available was used for sleep [4].

In the current study, resident physicians remained substantially impaired even after >4 hr of sleep; 50% of PVT sessions within this sleep duration bin had >3.21 attentional failures, a threshold that represents the average number of attentional failures observed among these same resident physicians during an intervention schedule (Figure 1). Thus, despite observing improvements after overnight sleep in this and other studies [7, 8, 10], this improvement is insufficient to restore performance postcall, which remains significantly suboptimal. Importantly, in our recent multicenter cluster-randomized crossover clinical trial of resident physicians (PGY-2 and PGY-3) at six U.S. pediatric intensive care units, we found a significant correlation between attentional failures and resident-physician-related serious medical errors, as assessed from observation and retrospective chart review [11]. Together these findings suggest that the risk of serious medical errors remains high postcall even when residents obtain >4 hr of sleep overnight.

A strength of the study is that it examined spontaneous behavior of resident physicians while working in intensive care units, and therefore, it has high operational validity. It did not examine the role of protected time for sleep overnight, as these policies are difficult to schedule, can affect continuity of care, and have minimal effect on sleep, as outlined above. This approach, however, led to an unequal distribution of data: each resident physician contributed multiple PVT sessions to one or more—but possibly not all—sleep bins. Despite this, an additional strength of the design is that all PVT sessions were matched for time of day and study week in the same resident physician during an intervention schedule, in which no EDWS was scheduled, to compare the relative levels of PVT performance impairment in a within-subject design. EDWS

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have been shown to reduce clinical performance substantially [12], and both acute and chronic sleep lead to performance equivalent to that while legally drunk [13–15]. In general, we are aware of only a few studies that have shown direct correlations between PVT attentional failures and other operationally relevant outcomes, such as on-the-road driving performance [16], simulated driving [17], and azimuth deviations on an Air Refueling Part Task Trainer [18]. As a sensitive measure of sustained or vigilant attention, the PVT findings from this study suggest that resident physicians working EDWS have an increased risk of committing errors related to impaired attention, a finding that is consistent with a parallel increase in medical error rates and worsening of another objective measure of attention derived from electrooculogram recordings in the same resident physicians on the traditional Q3 schedule compared with the intervention schedule [6].

Our findings are supportive of a growing body of data showing that, even if sleep is obtained, the underlying levels of acute and chronic sleep deprivation make sleep considerably less effective than previously thought in recovering performance [5, 19, 20]. In fact, our recent work indicates that repeated bouts of sleep loss and recovery impair performance more substantially than a shorter average duration of sleep scheduled equally each night [[19, 20]. Although such variable schedules are sanctioned by the ACGME, there are insufficient data on the time course of recovery from such extreme sleep deficiency, and even the dynamics of relatively minor challenges are dramatically underestimated by nearly all current models of sleep–wake regulation [19]. It is not known how sleep and wake are regulated under such extreme conditions. Relying on subjective sleepiness to assess fitness for duty is not tenable [7], as self-ratings of sleepiness are notoriously inconsistent with objective performance measures under conditions of chronic sleep loss [19, 20].

Despite modest improvements in PVT performance and ratings of sleepiness, protected sleep time does not translate into improvements in patient outcomes [7, 8]. Conversely, multiple studies have shown that eliminating EDWS and reducing continuous duty to 16 or fewer hours significantly improve both patient care and resident quality of life, including emotional exhaustion and burnout, and reduce motor vehicle crashes, medical errors, and percutaneous injuries [3, 21, 22]. Our findings demonstrate that PGY-1 resident physicians require more than 4 hr of sleep during overnight on-call shifts to improve next-day PVT performance and, even if they achieve this amount on rare occasions, they remain significantly impaired, providing important evidence for guiding the development of public policies related to the health and safety of resident physicians and their patients.

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