ANESTHESIOLOGY

Anesthesiology Resident Night Float Duty Alters Sleep Patterns

An Observational Study

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ABSTRACT

Background: Residency programs utilize night float systems to adhere to duty hour restrictions; however, the influence of night float on resident sleep has not been described. The study aim was to determine the influence of night float on resident sleep patterns and quality of sleep. We hypothesized that total sleep time decreases during night float, increases as residents acclimate to night shift work, and returns to baseline during recovery.

Methods: This was a single-center observational study of 30 anesthesia residents scheduled to complete six consecutive night float shifts. Electroencephalography sleep patterns were recorded during baseline (three nights), night float (six nights), and recovery (three nights) using the ZMachine Insight monitor (General Sleep Corporation, USA). Total sleep time; light, deep, and rapid eye movement sleep; sleep efficiency; latency to persistent sleep; and wake after sleep onset were observed.

Results: Mean total sleep time ± SD was 5.9 ± 1.9 h (3.0 ± 1.2.1 h light; 1.4 ± 0.6 h deep; 1.6 ± 0.7 h rapid eye movement) at baseline. During night float, mean total sleep time was 4.5 ± 1.8 h (1.4-h decrease, 95% CI: 0.9 to 1.9, Cohen's d = –1.1, $P < 0.001$) with decreases in light (2.2 ± 1.1 h, 0.7-h decrease, 95% CI: 0.4 to 1.1, d = –1.0, $P < 0.001$), deep (1.1 ± 0.7 h, 0.3-h decrease, 95% CI: 0.1 to 0.4, d = –0.5, $P = 0.005$), and rapid eye movement sleep (1.2 ± 0.6 h, 0.4-h decrease, 95% CI: 0.3 to 0.6, d = –0.9, $P < 0.001$). Mean total sleep time during recovery was 5.4 ± 2.2 h, which did not differ significantly from baseline; however, deep (1.0 ± 0.6 h, 0.4-h decrease, 95% CI: 0.2 to 0.6, d = –0.6, $P = 0.001$ *, $P = 0.001$) and rapid eye movement sleep (1.2 ± 0.8 h, 0.4-h decrease, 95% CI: 0.2 to 0.6, d = –0.9, $P < 0.001$ $P < 0.001$) were significantly decreased.

Conclusions: Electroencephalography monitoring demonstrates that sleep quantity is decreased during six consecutive night float shifts. A 3-day period of recovery is insufficient for restorative sleep (rapid eye movement and deep sleep) levels to return to baseline.

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Night float is one mechanism for fulfilling resident call responsibilities while avoiding prolonged clinical care that violates duty hours

What This Article Tells Us That Is New

- In anesthesiology residents conducting six consecutive nights of clinical care, three nights of recovery did not appear to restore normal sleep architecture, raising questions about this practice

To comply with resident duty hour restrictions implemented by the Accreditation Council for Graduate Medical Education in 2003[1] and revised in 2011,[2] many residency programs adopted a night float system. Numerous studies sought to determine the impact of duty hour regulations on the quality of patient care and resident education.[3–5] In a single-institution analysis of 14,610 surgical patients, institution of a night float system was associated with decreased mortality (1.9% *vs.* 1.1%; $P = 0.002$) and decreased surgical complications (48.3% *vs.* 38.6%; $P < 0.001$).[6] Radiology residents assigned to a night float rotation (9-h night shift for five consecutive nights) had fewer missed diagnoses compared to residents on a traditional overnight call schedule (15- to 23-h shifts every 9 to 10 nights; 1.0 *vs.* 1.69 missed diagnoses per shift, respectively; odds ratio, 0.55 [CI: 0.41 to 0.79]).[7]

Overnight and shift work contribute to sleep loss and disordered sleep. Residents working a night float shift are at risk for circadian misalignment, staying awake during the nighttime when the circadian drive to sleep is strongest, and sleep inertia, delayed time to reaching peak performance when waking up.[8] Impaired sleep may affect residents' well-being and ability to perform basic tasks. A study in surgical residents showed reduced efficiency and safety in

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performing simulated laparoscopy after a period of sleep deprivation that was worse with novices compared to experienced residents.[9] Longer work shifts have also been associated with lapses in attention,[10] medical errors,[11] increased risk of percutaneous injuries,[12] and greater risk for having a motor vehicle accident.[13]

Anesthesiology residency frequently requires extended shifts and overnight work. Fatigue and sleep deprivation present particular challenges for anesthesiology residents who must be constantly attentive in order to detect and rapidly respond to critical changes in a patient's status. We previously showed that after six consecutive night shifts, resident driving performance in a virtual-reality driving simulator is significantly impaired, including difficulty controlling driving speed, increased reaction times, and lapses in attention.[14] The effect of a night float system on anesthesiology resident sleep patterns and quality of sleep has not been investigated.

The aim of this observational study was to observe the electroencephalography sleep patterns of anesthesia residents before, during, and after completion of six consecutive night float shifts to determine the influence on sleep time, quality, and recovery. Daytime sleepiness was evaluated using the Epworth Sleepiness Scale. We hypothesized that total sleep time and quality are decreased during night float compared to baseline but increase over the six-shift night float period as residents acclimate to night shift work and return to baseline during the recovery period.

Materials and Methods

The study was approved by the University of Virginia Institutional Review Board (Charlottesville, Virginia; HSR-19763). This was a single-center observational study of anesthesia residents in postgraduate years two through four scheduled to complete six consecutive night float shifts. Subjects with a pacemaker or other implantable medical device or with history of a sleep disorder were excluded. Thirty-five anesthesia residents were approached between April 3, 2017, through July 12, 2018, and 30 subjects agreed to participate and provided written informed consent. Three subjects declined to participate, and two met exclusionary criteria.

Electroencephalographic sleep patterns were recorded at baseline (day 1 to 3), during night float (day 4 to 9) and during recovery (day 10 to 12) using the ZMachine Insight monitor (General Sleep Corporation, USA), a single-channel electroencephalography device with U.S. Federal Drug Administration clearance for ambulatory sleep staging. This device has 95.5% sensitivity and 92.5% specificity for detecting sleep when compared to polysomnographic scoring by a certified technician.[15] It was chosen for this study because of its simplicity and ease of use for residents over a 12-day study period. Residents were asked to wear the device during periods of nighttime sleep at baseline and recovery and during periods of daytime sleep after completing each night float shift. Total sleep time; time in light, deep, and rapid eye movement sleep; sleep efficiency; latency to persistent sleep; and wake after sleep onset were recorded. Each day, subjects were also asked to complete the Epworth Sleepiness Scale, a measure of daytime sleepiness with scores ranging from 0 to 24 with 0 to 5 lower normal, 6 to 10 higher normal, 11 to 12 mild excessive, 13 to 15 moderate excessive, and 16 to 24 severe excessive daytime sleepiness.[16]

In the original study protocol, we proposed to collect actigraphy and sleep data using Fitbit (Fitbit, USA) monitors to correlated to electroencephalography data; however, there were multiple technical problems with the Fitbit monitors, such as residents forgetting to charge the batteries, so this analysis was excluded from the study.

Statistical Analysis

Descriptive statistics are presented as number and proportion for dichotomous variables, and mean ± SD for continuous variables. Two-tailed hypothesis testing was used. A significance of $P < 0.05$ was considered significant. Linear mixed effect models were used to examine changes in sleep during each observation period (baseline [days 1 to 3], night float [days 4 to 9], and recovery [days 10 to 12]) and between observation periods. Data for each subject were collected for each day during the assessment period. Linear mixed effect models took into account the within-subject correlations of sleep changes across the 12 days of observation. Results are reported as mean, standard error of the estimate and difference from night float or baseline. A significance of $P < 0.05$ was considered significant. All analyses were performed in R version 3.3.2. (The R Foundation, Austria)[17]

To calculate effect sizes (Cohen's d) of the difference between baseline/nights/recovery, we first computed the mean of each variable for each participant during the respective observation period (*i.e.*, for each variable of interest, three values were computed for each participant). Cohen's d was then computed by comparing the averaged differences between each observation period. Cohen's d values of 0.2, 0.5, and 0.8 were considered small, medium, and large effect sizes, respectively.

Sleep Differences between Observation Periods

In order to compare the average sleep between night shifts and non–night shifts, we performed three sets of linear mixed effect models for each outcome variable. In each linear mixed effect model, subjects were included as random effects to allow a random intercept for each subject (*i.e.*, allow each subject to have a different starting value). The type of sleep period (baseline/night float/recovery) was included as a fixed effect. The type of sleep period was also included as random effects in each model to take into account individual variations in the differences of sleep during the other observed periods.

Three values for latency to persistent sleep greater than 230 s were excluded due to model nonconvergence. In

order to control family-wise error, statistical significance was adjusted with Bonferroni correction at α of 0.05 divided by the number of comparisons (n = 24).

Change in Sleep during Each Individual Observation Period

Change in sleep during each individual observation period (during baseline, night float, or recovery) was examined using linear mixed effect models. In each linear mixed effect model, subjects were included as random effects to allow a random intercept for each subject (*i.e.*, allow each subject to have a different starting value). Time (*i.e.*, day of observation; day 1 to 3 for baseline; day 4 to 9 for night float; day 10 to 12 for recovery) was included as a fixed effect; the estimated coefficient reflects the average change in sleep during the observed period. Time was also included as a random effect to take into account individual variations in the change in sleep during the observed period; models including random effect of time showed better, or no worse, fit than those without one. Three linear mixed effect models are performed for each outcome variable, assessing the change in sleep during baseline, night floats, and recovery. For ease of interpretation, we present results of the fixed effect regression coefficients in each model. In order to control family-wise error, statistical significance was adjusted with Bonferroni correction at α of 0.05 divided by the number of comparisons (n = 24).

Sample Size and Power Analysis

The sample size was chosen based on a power analysis based on our previous study data in which the mean hours slept daily over the 6-day night float period was 7.2 ± 0.7 h in the control group and 6.6 ± 0.1 h in the night float group.[14] Power was computed for paired samples *t* test because all participants are both in control and night float. Effect size for average hours slept daily over a 6-day period is 0.6 h. A sample size of 22 participants is needed to detect a difference in total sleep time of 0.6 h with 80% power at α of 0.05.

Results

The study Consolidated Standards of Reporting Trials diagram is shown in figure 1. Of the 35 subjects approached, 30 were enrolled, 2 subjects met exclusionary criteria due to diagnosed sleep disorder, and three declined participation. Twenty-nine subjects completed the study. One subject developed a rash from the electroencephalography electrodes and stopped the study on day 8. Mean age was 30 ± 3 yr. Twenty-four of the 30 subjects recruited (80%) were male; 18 of 30 (60%) were in postgraduate year 2, 5 of 30 (16.7%) were in postgraduate year 3, and 7 of 30 (23.3%) were in postgraduate year 4.

Electroencephalography

Time spent in different phases of sleep is shown in figure 2 with descriptive statistics shown in Supplemental Digital Content 1, http://links.lww.com/ALN/B958. Measures of

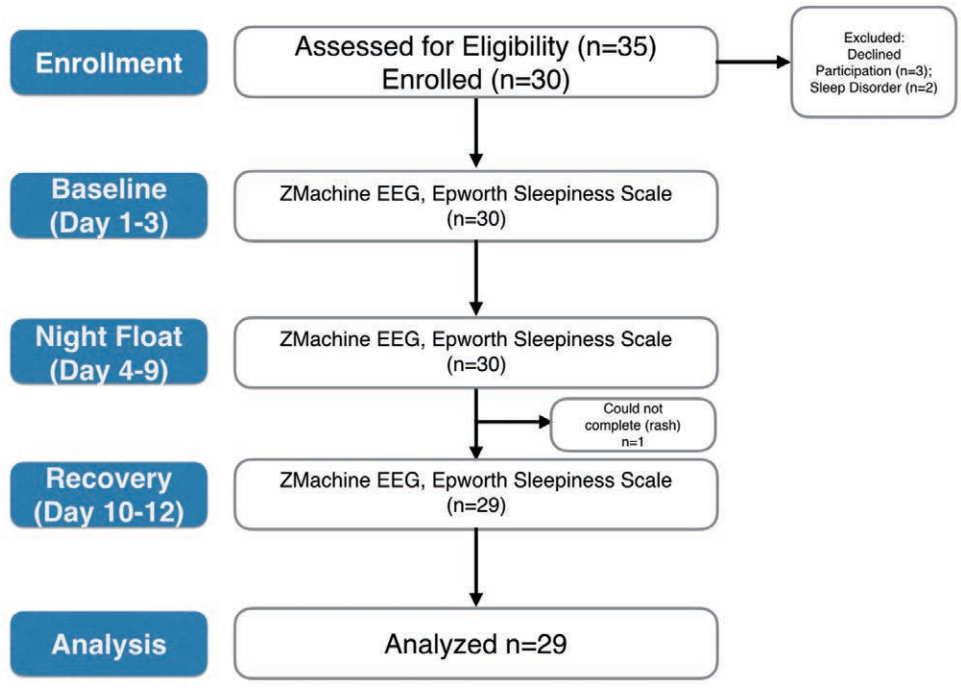

Fig. 1. Consolidated Standards of Reporting Trials diagram. EEG, electroencephalography.

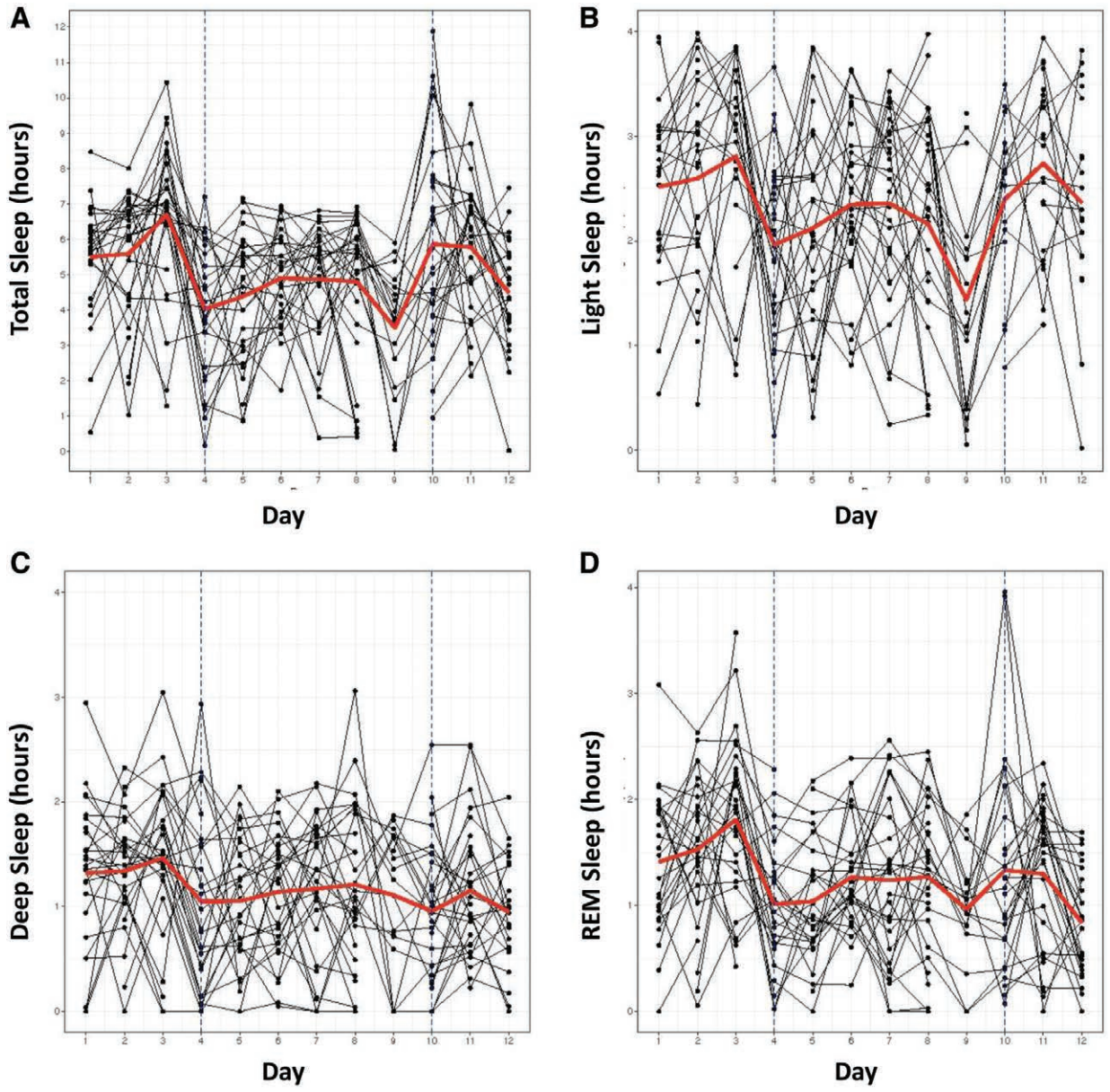

Fig. 2. (*A*) Total sleep time and time spent in (*B*) light, (*C*) deep, and (*D*) rapid eye movement (REM) sleep over the 12-day study period, including baseline (days 1 to 3), night float (days 4 to 9), and recovery (days 10 to 12). *Black lines* represent the raw data from each participant. The average value across all participants at each time point is represented in *red*.

sleep quality including sleep efficiency (fig. 2A), latency to persistent sleep (fig. 2B), and wake after sleep onset (fig. 2C) are shown in figure 3, and descriptive statistics are shown in Supplemental Digital Content 2, http://links.lww.com/ALN/B959. These graphs demonstrate a large degree of variation across individuals.

Of the 29 subjects who completed the study, complete electroencephalographic data were obtained for 12 of 30 subjects. Twelve additional subjects were missing data 1 of the 12 days. This occurred most frequently on day 9 because some residents did not nap during the daytime after they completed their night shift. The electroencephalography device was programed to record data for a 24-h epoch beginning from 4 PM until 4 PM the next day, and therefore no sleep was recorded on day 9. Of the subjects remaining, four were missing data for 2 of 12 days, one was missing 3 of 12 days, and one subject who dropped the study was missing data for 5 of 12 days. The electroencephalography device continuously monitors the quality of data input. If data were not of sufficient quality, no value was recorded for that day.

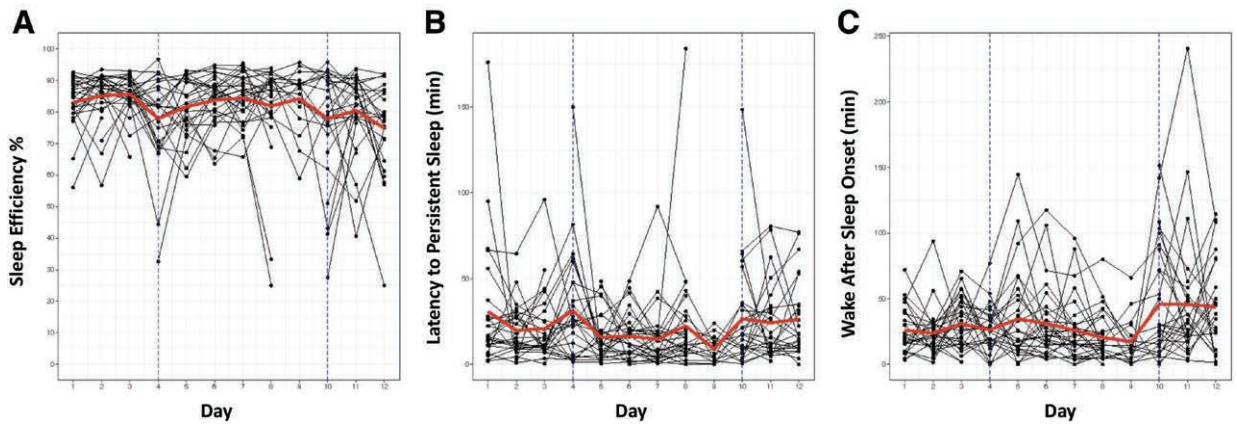

Fig. 3. (*A*) Sleep efficiency, (*B*) latency to persistent sleep, and (*C*) wake after sleep onset over the 12-day study period, including baseline (days 1 to 3), night float (days 4 to 9), and recovery (days 10 to 12). *Black lines* represent the raw data from each participant. The average value across all participants at each time point is represented in *red*.

Sleep Differences between Observation Periods

Differences in average sleep between observation periods were compared using linear mixed effect models (table 1). Mean baseline total sleep time was 5.9 ± 1.9 h with 3.0 ± 1.2 h in light, 1.4 ± 0.6 h in deep, and 1.6 ± 0.7 h in rapid eye movement sleep. Mean total sleep time during night float was 4.5 ± 1.8 h, a 1.4-h decrease from baseline (95% CI: 0.9 to 1.9, d = –1.1, $P < 0.001$), which was statistically significant at a Bonferroni-adjusted significance criterion of 0.002. During night float, mean time in light sleep was 2.2 ± 1.1 h (a 0.7-h decrease compared to baseline, 95% CI: 0.4 to 1.1, d = –1.0, $P < 0.001$), deep sleep 1.1 ± 0.7 h (a 0.3-h decrease compared to baseline, 95% CI: 0.1 to 0.4, d = –0.5, $P = 0.005$) and rapid eye movement sleep 1.2 ± 0.6 h (a 0.4-h decrease compared to baseline, 95% CI: 0.3 to 0.6, d = –0.9, $P < 0.001$). Reductions in light and rapid eye movement sleep were statistically significant; however, the reduction in deep sleep was not statistically significant at a Bonferroni-adjusted significance criterion of 0.002.

Mean total sleep time during recovery was 5.4 ± 2.2 h, which did not differ significantly from baseline (0.5-h decrease, 95% CI: –0.2 to 1.2, d = –1.1, $P = 0.151$). However, both deep (1.0 ± 0.6 h, 0.4-h decrease, 95% CI: 0.2 to 0.6, d = –0.6, $P = 0.001$) and rapid eye movement sleep (1.2 ± 0.8, 0.4-h decrease, 95% CI: 0.2 to 0.6, d = –0.9, $P < 0.001$) decreased during recovery compared to baseline, which were statistically significant differences at aBonferroni-adjusted significance criterion of 0.002. Deep and rapid eye movement sleep are restorative phases of sleep, and reductions of these phases may suggest impaired recovery after night float.

There were no differences in measures of sleep quality (sleep efficiency, latency to persistent sleep, or wake after sleep onset) during night float compared to baseline. However, sleep efficiency decreased by 6.8% during the recovery period (77.8 ± 15.2%) compared to baseline (84.6 ± 7.4%; 95% CI: 2.9 to 10.7, d = –0.3, $P = 0.002$). Latency to persistent sleep increased during recovery (25.7 ± 25.0 min) compared to night float (18.9 ± 23.2 min; 6.9 min difference, 95% CI: –12.4 to –1.4, d = –0.3, $P = 0.02$) and wake after sleep onset increased during recovery (45.1 ± 42.7 min) compared to both baseline (26.9 ± 18.3 min, 17.2 min difference, 95% CI: 29.0 to 5.3, d = 0.0, $P = 0.008$) and night float periods (26.7 ± 24.8, 17.8 min difference, 95% CI: –30.1 to –5.5, d = 0.0, $P = 0.008$). Although these results were not statistically significant at a Bonferroni-adjusted significance correction of $P = 0.002$, they suggest that sleep quality may be impaired during recovery due to difficulty falling asleep and staying asleep.

Change in Sleep during Each Individual Observation Period

Change in sleep during each individual observation period (baseline, night float, or recovery) was examined using linear mixed effect models (table 2). There were no significant changes in sleep in any of the individual observation periods at a Bonferroni-adjusted significance criterion of 0.002.

Epworth Sleepiness Scale

Perceived daytime sleepiness was measured using the Epworth Sleepiness Scale (fig. 4). Differences in Epworth Sleepiness Scale score between observation periods and in each observation period are shown in tables 1 and 2, respectively. Mean Epworth Sleepiness Scale score was 6.8 ± 4.0 at baseline, 10.0 ± 4.9 during night float (an increase of 3.2 compared to baseline, 95% CI: 1.9 to 4.5, d = 0.9, $P < 0.001$), and 8.7 ± 4.6 during recovery (an increase of

Table 1. Descriptive Statistics and Results from Linear Mixed Effects Model Examining Sleep Differences between Observation Periods

	Mean ± SD [Min, Max]	Compared with Baseline		Compared with Night Float	
		d [95% CI]	Contrast [95% CI]	d [95% CI]	Contrast [95% CI]
Total sleep time (h)					
Baseline	5.9 ± 1.9 [0.5, 10.4]				
Night float	4.5 ± 1.8 [0.1, 7.2]	–1.1 [–1.7, –0.5]	1.4 [0.9, 1.9], $P < 0.001$*		
Recovery	5.4 ± 2.2 [0.0, 11.9]	–1.1 [–1.7, –0.5]	0.5 [–0.2, 1.2], $P = 0.15$	–1.2 [–1.8, –0.6]	–0.9 [–1.4, 0.4], $P < 0.001$*
Light (h)					
Baseline	3.0 ± 1.2 [0.4, 6.2]				
Night float	2.2 ± 1.1 [0.1, 5.6]	–1.0 [–1.6, –0.4]	0.7 [0.4, 1.1], $P < 0.001$*		
Recovery	3.2 ± 1.4 [0.0, 7.0]	–1.0 [–1.5, –0.4]	–0.2 [–0.7, 0.2], $P = 0.30$	–1.0 [–1.5, –0.4]	–1.0 [–1.3, –0.7], $P < 0.001$*
Deep (h)					
Baseline	1.4 ± 0.6 [0.0, 3.0]				
Night float	1.1 ± 0.7 [0.0, 3.1]	–0.5 [–1.0, 0.0]	0.3 [0.1, 0.4], $P = 0.005$		
Recovery	1.0 ± 0.6 [0.0, 2.5]	–0.6 [–1.1, 0.0]	0.4 [0.2, 0.6], $P = 0.001$*	–0.6 [–1.1, 0.0]	0.1 [–0.1, 0.3], $P = 0.23$
REM (h)					
Baseline	1.6 ± 0.7 [0.0, 3.6]				
Night float	1.2 ± 0.6 [0.0, 2.6]	–0.9 [–1.4, –0.3]	0.4 [0.3, 0.6], $P < 0.001$*		
Recovery	1.2 ± 0.8 [0.0, 4.0]	–0.9 [–1.5, –0.3]	0.4 [0.2, 0.6], $P < 0.001$*	–0.9 [–1.5, –0.4]	0.0 [–0.2, 0.1), $P = 0.75$
SE (%)					
Baseline	84.6 ± 7.4 [56.0, 93.3]				
Night float	82.2 ± 11.3 [25.0, 96.6]	–0.3 [–0.8, 0.2]	2.3 [–0.5, 5.1], $P = 0.11$		
Recovery	77.8 ± 15.2 [25.0, 95.7]	–0.3 [–0.9, 0.2]	6.8 [2.9, 10.7], $P = 0.002$*	–0.3 [–0.8, 0.2]	4.3 [0.8 to 7.8], $P = 0.02$
LPS (min)					
Baseline	23.5 ± 25.3 [0.5, 176.0]				
Night float	18.9 ± 23.2 [0.0, 184.0]	–0.3 [–0.8, 0.3]	4.5 [–3.2, 12.2], $P = 0.27$		
Recovery	25.7 ± 25.0 [0.0, 148.5]	–0.2 [–0.7, 0.3]	–3.0 [–9.5, 3.6], $P = 0.38$	–0.3 [–0.8, 0.3]	–6.9 [–12.4, –1.4], $P = 0.02$
WASO (min)					
Baseline	26.9 ± 18.3 [1.5, 94.0]				
Night float	26.7 ± 24.8 [0.0, 144.5]	–0.1 [–0.6, 0.4]	0.8 [–4.9. 6.5], $P = 0.78$		
Recovery	45.1 ± 42.7 [0.0, 240.5]	0.0 [–0.6, 0.5]	17.2 [29.0, 5.3], $P = 0.008$	0.0 [–0.5, 0.5]	–17.8 [–30.1, –5.5], $P = 0.008$
ESS					
Baseline	6.8 ± 4.0 [0.0, 18.0]				
Night float	10.0 ± 4.9 [2.0, 21.0]	0.9 [0.3, 1.5]	3.2 [1.9, 4.5], $P < 0.001$*		
Recovery	8.7 ± 4.6 [1.0, 21.0]	0.9 [0.3, 1.5]	–2.0 [–3.5, –0.5], $P = 0.02$	0.9 [0.3, 1.5]	1.2 [–0.3, 2.7], $P = 0.13$

d indicates Cohen's d (standardized effect size). The contrast columns indicate unstandardized effect size and refer to contrast estimated from the linear mixed effects model, taking into account within-patient correlations.

*Significant result at Bonferroni adjusted significance criterion $P = 0.002$.

ESS, Epworth Sleepiness Scale; LPS, latency to persistent sleep; Max, maximum; Min, minimum; REM, rapid eye movement; SE, sleep efficiency; WASO, wake after sleep onset.

2.0 compared to baseline, 95% CI: –3.5 to –0.5, d = 0.9, $P = 0.02$), though this was not statistically significant at a Bonferroni-adjusted significance criterion of 0.002. There was a statistically significant increase in Epworth Sleepiness Scale by 0.7 ± 0.2 over the 6-day night float period ($P < 0.001$). Mean Epworth Sleepiness Scale scores throughout the study period were consistent with higher normal levels of daytime sleepiness (Epworth Sleepiness Scale score 6 to 10), and the clinical effects may be negligible.

Discussion

Creation of a night float system is one strategy residency programs adopt in order to comply with Accreditation Council for Graduate Medical Education duty hour restrictions; however, the superiority of a night float system over more traditional call structures (*i.e.*, "24-h shift") for resident sleep has not been established. Several studies have reported benefits of a night float system, including increased amount of sleep and personal time and improved nursing communication and quality of patient care for surgery residents.[18] In obstetrics and gynecology, residents reported reduced fatigue, improved continuity of patient care, and no adverse effects on surgical experience or quality of life after the transition to four consecutive night float shifts.[19]

In a pilot study, urology residents were assigned to one of three schedules: a 12-h day shift (Monday through Friday), 12-h night float (Sunday through Friday), or 24-h home call, and actigraphy was used to measure total sleep time, sleep latency, and depth of sleep. There was no change in total sleep time or quality of sleep with night float compared to day shift or 24-h call.[20] Unfortunately, actigraphy has significant limitations in determining sleep patterns. Importantly, studies have shown that the accuracy of actigraphy to detect sleep and wakefulness declines as sleep efficiency decreases, as is seen with disordered sleep.[21] Additionally, actigraphy

Table 2. Results from Linear Mixed Effects Model Examining Change in Sleep at Each Observation Period

	Mean ± Standard Error of the Estimate	*P* Value
Total Sleep Time (h)		
Baseline	0.6 ± 0.2	*P* = 0.01
Night float	0.0 ± 0.1	*P* = 0.98
Recovery	–0.7 ± 0.3	*P* = 0.06
Light (h)		
Baseline	0.3 ± 0.2	*P* = 0.04
Night float	–0.0 ± 0.5	*P* = 0.44
Recovery	–0.4 ± 0.2	*P* = 0.03
Deep (h)		
Baseline	0.1 ± 0.1	*P* = 0.32
Night float	0.0 ± 0.0	*P* = 0.45
Recovery	0.0 ± 0.1	*P* = 0.98
REM (h)		
Baseline	0.2 ± 0.1	*P* = 0.02
Night float	0.0 ± 0.0	*P* = 0.49
Recovery	–0.2 ± 0.1	*P* = 0.04
SE (%)		
Baseline	1.3 ± 1.0	*P* = 0.18
Night float	0.6 ± 0.4	*P* = 0.14
Recovery	–1.3 ± 2.2	*P* = 0.56
LPS (min)		
Baseline	–4.6 ± 3.2	*P* = 0.16
Night float	–1.8 ± 1.0	*P* = 0.07
Recovery	0.0 ± 3.3	*P* = 0.99
WASO (min)		
Baseline	2.6 ± 2.3	*P* = 0.25
Night float	–2.4 ± 1.0	*P* = 0.02
Recovery	–1.8 ± 4.7	*P* = 0.70
ESS		
Baseline	–0.2 ± 0.3	*P* = 0.63
Night float	0.7 ± 0.2	*P* < 0.001*
Recovery	–1.1 ± 0.6	*P* = 0.07

*Significant result at Bonferroni adjusted significance criterion *P* = 0.002.

ESS, Epworth Sleepiness Scale; LPS, latency to persistent sleep; REM, rapid eye movement; SE, sleep efficiency; WASO, wake after sleep onset.

is unable to determine changes in the phases of sleep. Electroencephalography remains the accepted standard to investigate sleep and sleep disorders, and single-channel electroencephalography provides substantial agreement with polysomnography in assessing rapid eye movement, sleep stages, and other important parameters.[15]

Our study investigates the effect of a night float schedule on anesthesia resident sleep patterns and quality of sleep using a commercially available, single-channel electroencephalography recording device. Here, we report several key findings. Mean baseline total sleep time among our anesthesia residents was 5.9 ± 1.9 h. This is greater than 1 h less than the 7 h recommended by the American Academy of Sleep Medicine and Sleep Research Society in their 2015 Joint Consensus Statement[22] and suggests that residents in this study are sleep-deprived at baseline. Mean total sleep time during night float was 4.5 ± 1.8 h, a decrease of 1.4 h compared to baseline, which is statistically significant ($P < 0.001$) with a large effect size (d = –1.1). According to the Consensus Statement, adults who sleep less than 7 h per night regularly are at risk for adverse health effects including weight gain and obesity, diabetes, hypertension, heart disease and stroke, depression, and increased risk of death.[22] Sleeping less than 7 h is also associated with impaired immune function, increased pain, impaired performance, increased errors, and greater risk of accidents,[22,23] all of which may adversely affect resident education and the ability to provide safe medical care.

Despite the additional sleep deprivation observed during night float, we did not observe an increase in total sleep during the recovery period, as may have been expected based on previous studies.[24] Instead, total sleep time during recovery did not differ statistically significantly from baseline. However, time spent in deep and rapid eye movement sleep were both decreased by 0.4 h compared to baseline, which were statistically significant decreases ($P = 0.001$ and $P < 0.001$, respectively) with moderate (d = –0.6) and large (d = –0.9) effect sizes, respectively. Sleep quality was statistically significantly impaired during recovery, as demonstrated by a decrease in sleep efficiency by 6.8% compared to baseline ($P = 0.002$), increase in latency to persistent sleep by 6.9 min ($P = 0.020$) compared to night float, and increase in wake after sleep onset by 17.2 min compared to baseline ($P = 0.008$). Although only the changes in sleep efficiency were significant at the Bonferroni α criterion, these findings suggest that a 3-day recovery period is insufficient for recovery of normal sleep patterns after consecutive night float shifts.

Previous studies support the finding that longer recovery times may be necessary. Kitamura *et al.* investigated individual optimal sleep duration and potential sleep debt among 15 men enrolled in a sleep study protocol in which they were given the opportunity to sleep up to 12 h for 9 consecutive days.[23] Mean at-home sleep time was 7.3 h, while optimal sleep duration was 8.4 ± 0.2 h. The authors reported that for every 1 h of sleep debt, up to 9 days of sufficient sleep is necessary for normalization of daytime sleepiness, sleep structure, and neuroendocrine function, including levels of glycometabolic and stress hormones. Banks *et al.* randomized 159 healthy adults to either sleep restriction of 4 h for five consecutive nights followed by one night of recovery sleep for 2, 4, 6, 8, or 10 h or a control group allowed 10 h in bed each night and found residual neurobehavioral deficits in the sleep-restricted group even after 10 h of recovery sleep.[24] Future studies investigating optimal recovery after overnight and night shift schedules of varying length are necessary.

This study has several limitations. Due to resident schedule limitations, schedule assignment during the 3 days before night float could not be standardized. Some variation in baseline sleep may exist due to differences in assignment (*i.e.*, operating room *vs.* off-service and day call *vs.* noncall shift). Another limitation is that residents were asked to wear the electroencephalography device only during periods of

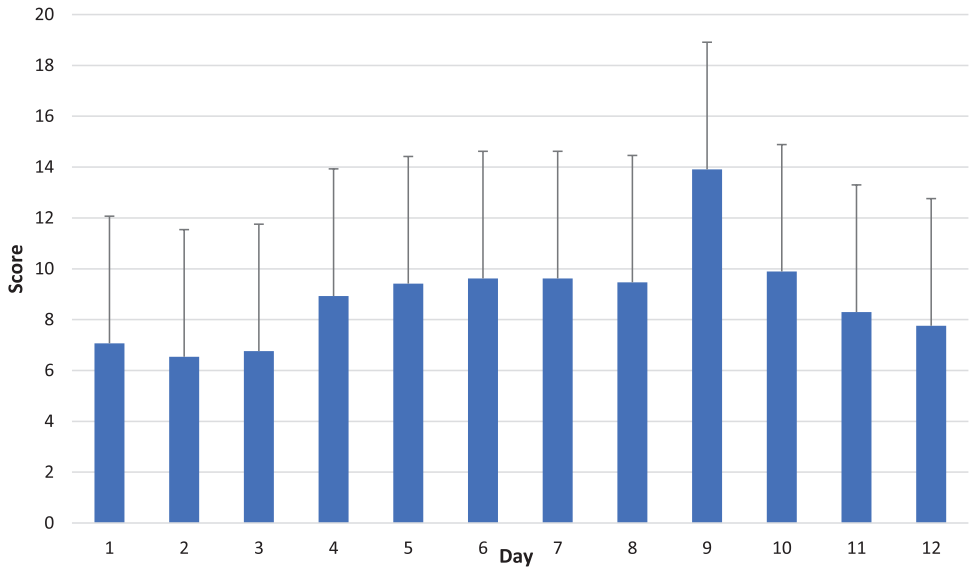

Fig. 4. Epworth Sleepiness Scale results measuring perceived daytime sleepiness over the 12-day study period, including baseline (days 1 to 3), night float (days 4 to 9), and recovery (days 10 to 12).

nighttime sleep during baseline and recovery and daytime sleep after a night float shift. They were not required to wear the device during periods of wakefulness or if they were able to nap during the night float shift. Although we believe the time available for residents to "nap" while on night float is very limited, total amount of sleep during night float may be underestimated.

Finally, this was an observational study in which we evaluated only one approach to the need to provide continuous coverage for the 24-h operating room. We did not include a traditional call system (*i.e.*, every third night "Q3" 24-h call) for comparison. Night float systems were incorporated into resident training programs because it is believed that they are less harmful and result in better patient care than traditional call systems. Although a limited number of primarily qualitative studies have shown that night float is no worse than traditional call systems, our data suggest that it may still contribute to significant sleep disruption. The consequences of sleep disruption during night float on clinically relevant outcomes are unknown. Future studies are needed to address this important question.

This study investigates the effect of a night float schedule on sleep patterns and quality using electroencephalography. We demonstrate that sleep is significantly impaired during night float and that a 3-day recovery period is insufficient for sleep patterns to return to baseline. This suggests that despite some of the clinical advantages of night float systems, there may be significant disadvantages for resident sleep and overall wellness. Our results identify several avenues for future study including the effect of alternative night shift and call schedules on resident sleep, recovery, and performance. Studies such as these may help elucidate how changes in duty hour restrictions and schedule impact resident education and patient-related outcomes.

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Competing Interests

The authors declare no competing interests.

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