

Napping on the Night Shift: A Study of Sleep, Performance, and Learning in Physicians-in-Training

JENNIFER McDONALD, PhD
DARRYL POTYK, MD, FACP
DAVID FISCHER, MD
BRETT PARMENTER, PhD
TERESA LILLIS, MA, PhD (CAND)
LINDSEY TOMPKINS, MS
ANGELA BOWEN, MA, PhD (CAND)
DEVON GRANT, MS, PhD (CAND)
AMANDA LAMP, BS
GREGORY BELENKY, MD, FAPA

Abstract

Background Physicians in training experience fatigue from sleep loss, high workload, and working at an adverse phase of the circadian rhythm, which collectively degrades task performance and the ability to learn and remember. To minimize fatigue and sustain performance, learning, and memory, humans generally need 7 to 8 hours of sleep in every 24-hour period.

Methods In a naturalistic, within-subjects design, we studied 17 first- and second-year internal medicine residents working in a tertiary care medical center, rotating between day shift and night float every 4 weeks. We studied each resident for 2 weeks while he/she worked the day shift and for 2 weeks while he/she worked the night float, objectively measuring sleep by wrist actigraphy, vigilance by the Psychomotor Vigilance

Task test, and visual-spatial and verbal learning and memory by the Brief Visuospatial Memory Test-Revised and the Rey Auditory-Verbal Learning Test.

Results Residents, whether working day shift or night float, slept approximately 7 hours in every 24-hour period. Residents, when working day shift, consolidated their sleep into 1 main sleep period at night. Residents working night float split their sleep, supplementing their truncated daytime sleep with nighttime on-duty naps. There was no difference in vigilance or learning and memory, whether residents worked day shift or night float.

Conclusions Off-duty sleep supplemented with naps while on duty appears to be an effective strategy for sustaining vigilance, learning, and memory when working night float.

Jennifer McDonald, PhD, is Therapist, The Emily Program, Seattle; Darryl Potyk, MD, FACP, is Assistant Program Director, Providence Internal Medicine Residency, and Clinical Professor of Medicine, Department of Medicine, University of Washington School of Medicine; David Fischer, MD, is Internist, Spokane Internal Medicine, and Lead Resident during this study; Brett Parmenter, PhD, is Clinical Assistant Professor, VA Puget Sound Health Care System; Teresa Lillis, MA, is PhD candidate in Clinical Psychology, Department of Psychology, University of Kansas; Lindsey Tompkins, MS, is Lead Research Coordinator, Rockford Cardiovascular Group; Angela Bowen, MA, is PhD candidate, Department of Industrial and Organization Psychology, Colorado State University; Devon Grant, MS, is Study Coordinator, Sleep and Performance Research Center, Washington State University, and PhD candidate, Department of Experimental Psychology, Washington State University; Amanda Lamp, BS, is Research Assistant, Sleep and Performance Research Center, Washington State University; and Gregory Belenky, MD, FAPA, is Research Professor and Director, Sleep and Performance Research Center, Washington State University.

Funding: This study was funded by United States Army Medical Research and Materiel Command award W81XWH-05-0099.

The United States Army Medical Research and Materiel Command had no role in the design and conduct of the study; the collection, management, analysis, and interpretation of data; and the preparation, review, or approval of the manuscript.

The authors would like to thank Hans P. A. Van Dongen, PhD, Sleep and Performance Research Center, Washington State University, for expert guidance with the statistical analysis of the study.

Corresponding author: Gregory Belenky, MD, FAPA, Sleep and Performance Research Center, PO Box 1495, Washington State University, Spokane, WA 99210-1495, belenky@wsu.edu

Editor's Note: The online version of this article contains the schematic of the study design.

Introduction

Residents must perform, learn, and remember, despite sleep loss, working nights, and high workload.^{1,2} Night shift workers experience fatigue and degraded cognitive performance across multiple occupations and work settings.³⁻⁹ Total sleep time in a 24-hour period is the primary sleep-related determinant of performance, whether that sleep is in a consolidated single bout of 7 to 8 hours or split into 2 or 3 bouts.¹⁰⁻¹² Split sleep, including main off-duty daytime sleep with on-duty naps, may sustain resident performance when working nights. We studied the amount and distribution of sleep in residents working day shift and night float and the effects on their vigilance performance (reaction time) and their ability to learn and remember.

Received October 25, 2012; revision received March 22, 2013; accepted May 22, 2013.

DOI: <http://dx.doi.org/10.4300/JGME-D-12-00324.1>

Methods

Setting and Participants

Seventeen internal medicine residents working in a tertiary care hospital were studied (4 women, 13 men; mean $\pm$ SD age for women was 29.25 ± 3.59 years old and 30.77 ± 6.00 years old for men; mean age for the entire study sample of 17 was 30.41 ± 5.47 years old [range 26–50 years; interquartile range 28–31 years]). There was no significant difference in age between the women and the men ($t = 0.62$; $df = 8.748$; $P = .55$). The proportion of women to men in the study sample did not differ significantly from that of the cohort from which the study sample was drawn (17 women to 22 men) as indicated by test results for equality of proportions, which approached but did not reach significance (χ^2 test = 3.59; $df = 1$; $P = .06$). The study sample included all residents in the overall cohort of 39 who were willing to volunteer. One male participant was 50 years old and an outlier with respect to age.

Intervention

Residents alternated between day shift and night float rotations, each rotation lasting 4 weeks. Residents on the day shift worked from 7:00 AM to 6:00 PM, 6 days a week. Residents on night float worked from 5:30 PM to 7:00 AM the following day, 5 days a week. This was a normal rotation schedule; there was no experimental schedule manipulation. No formal provision for on-shift napping or protected time for sleep was provided, although residents were allowed to sleep when they could. On-call rooms were available. Each resident was studied 4 times: (1) during the last week of a day shift rotation; (2) during the first week of the subsequent night float rotation; (3) during the last week of this night float rotation; and (4) during the first week of the subsequent day shift rotation (a schematic of the study design is provided as online material).

The Institutional Review Board at Washington State University and the Office of Research Protections of the United States Army Research and Materiel Command approved the research protocol and consent form.

Outcomes

Sleep Data Each resident wore a wrist activity monitor (actigraph; Micro Motionlogger Sleep Watch; Ambulatory Monitoring Inc, Ardsley, NY) continuously to measure sleep. The actigraph activity record was scored by a sleep/wake scoring algorithm (Action W-2 software; Ambulatory Monitoring). This yielded a minute-by-minute continuous sleep/wake history, documenting main sleep and naps. Actigraphy accurately measures total sleep time per 24 hours and is comparable to polysomnography in this respect.^{13–16} Total sleep time per 24 hours was

What was known

Residents may experience fatigue due to limited or disrupted sleep while working night shifts, which may affect cognitive abilities.

What is new

A study examines first- and second-year internal medicine residents' cognitive abilities on day and night shifts over a 4-week period.

Limitations

Small sample, single-institution study limit generalizability.

Bottom line

Residents' cognitive abilities did not differ between day and night shifts. Sleep averaged 7 to 8 hours in a 24-hour period during both shifts, with naps supplementing sleep on the night shifts.

calculated by summing main sleep and naps from noon to noon for each day of day shift and from midnight to midnight for each day of night float. Off-duty sleep was calculated by adding the number of minutes of sleep occurring outside of the resident's work shift. On-duty sleep was calculated by adding the number of minutes slept during the resident's work shift. On- and off-duty times were derived from the time stamps of the Psychomotor Vigilance Task (PVT) tests taken going on shift and going off shift.

Vigilance Performance Residents completed a 10-minute PVT test at shift beginning and shift end for all shifts during the studied periods. The PVT test is a serial reaction time test implemented on a smart phone. Each PVT is date and time stamped. The PVT test is a measure of vigilance and is sensitive to sleep loss.^{17–20}

Learning The Rey Auditory-Verbal Learning Test (RAVLT) is a test of verbal learning and memory measuring immediate memory span, new learning, susceptibility to interference, and recognition memory.²¹ The Brief Visuospatial Memory Test-Revised (BVMT-R) is a test of visual memory measuring visual learning and memory via immediate recall, acquisition rate, delayed recall, and recognition.²¹ The RAVLT and the BVMT-R were administered 4 times, once at the end of each studied week.

Analysis

Data were analyzed using mixed effects analysis of variance.^{22,23} Each resident served as his or her own control by working in both day shift and night float rotations, increasing statistical power.

Results

The residents ($n = 17$) worked longer hours on the night float (TABLE). Actigraphically measured total sleep times

TABLE

PRIMARY OUTCOMES—HOURS WORKED/24 HOURS, TOTAL SLEEP TIME/24 HOURS (ON-SHIFT AND OFF-SHIFT), VIGILANCE PERFORMANCE, AND VERBAL AND VISUAL-SPATIAL LEARNING AND MEMORY IN RESIDENTS WORKING DAY SHIFT AND THE SAME RESIDENTS WORKING NIGHT FLOAT

Primary Outcome	Day Shift	Night Float	F Value, <i>df</i> , and <i>P</i>
Hours worked/24 h ^a	9.0 ± 0.2 SEM	13.4 ± 0.2 SEM	$F[1,277] = 506.4; P < .01$
Total sleep time (h)/24 h	7.0 ± 0.3 SEM	6.8 ± 0.2 SEM	$F[1,225] = 0.27; P = .60$
No. of on-shift sleep h/24 h ^a	0.1 ± 0.2 SEM	2.6 ± 0.2 SEM	$F[1,166] = 167.4; P < .01$
No. of off-shift sleep h/24 h ^a	6.8 ± 0.2 SEM	3.8 ± 0.2 SEM	$F[1,166] = 144.9; P < .01$
Psychomotor Vigilance Task (PVT) test reaction time (ms) ^b	382 ± 28 SEM	393 ± 28 SEM	$F[1,500] = 2.81; P = .09$
Visuospatial learning (total recall)—BVMT-R	25.5 ± 1.1 SEM	26.6 ± 1.1 SEM	$F[1,50] = 0.98; P = .33$
Visuospatial learning (memory/delayed recall)—BVMT-R	10.0 ± 0.3 SEM	9.5 ± 0.3 SEM	$F[1,50] = 1.09; P = .30$
Visuospatial learning (% information retained)—BVMT-R	96.5 ± 2.2 SD	92.5 ± 2.2 SD	$F[1,50] = 1.65; P = .20$
Visuospatial learning (recognition index)—BVMT-R	5.9 ± 0.1 SEM	5.8 ± 0.1 SEM	$F[1,50] = 1.81; P = .18$
Verbal learning (total recall)—RAVLT	59.2 ± 1.6 SEM	57.7 ± 1.6 SEM	$F[1,50] = 1.47; P = .23$
Verbal learning (memory/delayed recall)—RAVLT	12.3 ± 6.5 SEM	12.2 ± 6.5 SEM	$F[1,50] = 0.10; P = .75$
Verbal learning (% information retained)—RAVLT	90.3 ± 3.4 SD	89.1 ± 3.4 SD	$F[1,50] = 0.26; P = .61$
Verbal learning (recognition index)—RAVLT	13.2 ± 0.5 SEM	13.1 ± 0.5 SEM	$F[1,50] = 0.08; P = .77$

Abbreviations: SEM, standard error of the mean; SD, standard deviation; BVMT-R, Brief Visuospatial Memory Test-Revised; RAVLT, Rey Auditory-Verbal Learning Test.

^a Denotes statistical significance.

^b There were no significant changes in PVT test times from shift beginning to shift end (mean PVT test times at shift beginning = 382 ms ± 28 SEM; mean PVT test times at shift end = 392 ms ± 28 SEM; $F[1,500] = 2.35; P = .13$) and no interactions between shift beginning and shift end and rotation (night float or day shift); $F[1,500] = 0.59; P = .44$. As a result, PVT test times averaged across beginning and end of shift were used for this analysis.

per 24 hours did not differ between day shift and night float (TABLE). Although sleep time did not differ, how sleep was divided between on- and off-duty times did differ between night float and day shift. For 16 residents, for whom we had PVT time stamps going on and off shift, we were able to determine not only total sleep time per 24 hours but also how this sleep was divided between on- and off-duty times. Residents working night float split their sleep into a main off-duty daytime sleep and supplemental on-duty nighttime naps. Residents working day shift consolidated their sleep into a main off-duty nighttime sleep without appreciable daytime nap supplementation (TABLE).

PVT test administration at shift beginning and shift end occurred on average at 8:40 AM and 4:49 PM for the day shift and at 5:57 PM and 7:15 AM the following day for night float. Thus, testing occurred at approximately the same time of day for both rotations. There was no change in PVT reaction time from shift beginning to shift end and no interaction between shift beginning/shift end and rotation (day shift or night float). Given the lack of main effect and interaction, we averaged going-on-shift and going-off-shift reaction time values and used them in the analysis.

Vigilance as measured by PVT reaction time did not differ between the night float and day shift (TABLE).

For both the verbal learning (RAVLT) and the visual-spatial tests (BVMT-R), a score consisting of total correct for all trials on each test (total recall) was calculated. A memory score was also tabulated (delayed recall). There were no significant differences in these measures in residents when working night float versus when working day shift (TABLE).

Discussion

Residents maintained equivalent total sleep time per 24 hours, vigilance performance, and ability to learn and remember verbal and visual spatial information working night float and day shift.

The equivalent total sleep time per 24 hours resulted from different sleep strategies, with residents working the day shift consolidating their sleep into a single, nighttime main sleep and splitting their sleep into a daytime main sleep supplemented by nighttime, on-duty naps when working night float.²⁴ The addition of on-duty, nighttime sleep to off-duty daytime sleep when working night float yielded an equivalent total sleep time per 24 hours

compared to day shift, apparently sustaining vigilance performance, learning, and memory equivalent to that observed when working day shift. Existing strategies of fatigue mitigation focus on the relationship between work hours and performance. The present study focused on total sleep time, shifting the strategy of fatigue mitigation from rules regulating work hours to policy and procedures ensuring adequate sleep.

The present results were obtained under naturalistic conditions without mandated on-duty napping or protected time for on-duty sleep. Two prior studies have examined mandated, protected sleep time for residents working extended shifts. In the first study,²⁵ residents were provided 4 hours of protected sleep time during a 36-hour shift. No increase in total sleep time or change in performance was found. A more recent study²⁶ offered residents 7 hours of protected sleep time during a 30-hour shift. Only 22% of interns took the offered sleep opportunity, citing a desire to care for their own patients and concerns about continuity of care. Thus, there could be unforeseen consequences of scheduled, mandated napping, especially in smaller residency programs. In a still more recent randomized controlled trial,²⁷ 106 interns and senior medical students worked a normal intern schedule or a protected sleep schedule (protected time from 12:30 AM to 5:30 AM). There was good compliance with the protected schedule. The protected sleep period increased overnight sleep duration and improved subsequent alertness relative to the normal schedule.

By self-report, the residents in our study indicated that the timing of admissions determined their ability to obtain on-duty sleep. The most desirable time was the period between 1:00 AM and 5:00 AM, if admission-free. Our findings suggest that the opportunity to sleep on duty enabled residents working night float to supplement their daytime, off-duty sleep and maintain their total sleep time, vigilance performance, and ability to learn. The present exploratory, naturalistic study suggests that on-duty napping could mitigate the effects of fatigue from extended work hours and night shift work. Further research is needed to determine the utility of nighttime on-duty napping as a formal, mandated strategy for fatigue mitigation.

Limitations of our study include a small sample of residents at a single institution and few women in the study sample. Also, the lack of a difference in total sleep time per 24 hours, vigilance performance, and ability to learn and remember verbal and visual spatial information between day shift and night float could reflect inadequate statistical power, given the small sample size. Finally, our measures of vigilance, memory, and learning may not equate to clinical or procedural performance.

Conclusion

Our findings suggest a new approach to fatigue mitigation, shifting the focus of fatigue mitigation from limiting work hours to ensuring adequate sleep.

References

- 1 Balkin TJ. Performance deficits during sleep loss: effects of time awake, time of day, and time on task. In: Kryger MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. 5th ed. St Louis, MO: Elsevier; 2011:738–744.
- 2 Belenky G, Åkerstedt T. Occupational sleep medicine: introduction. In: Kryger MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. 5th ed. St Louis, MO: Elsevier; 2011:734–737.
- 3 Drake CL, Wright KP. Shift work, shift-work disorder, and jet lag. In: Kryger MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. 5th ed. St Louis, MO: Elsevier; 2011:784–798.
- 4 Rosekind MR. An NTSB perspective on sleep/fatigue risks in transportation: accidents, recommendations, and future needs. The sleepy brain, Stockholm, Sweden, June 27, 2011. US National Transportation Safety Board. http://www.ntsb.gov/doclib/speeches/rosekind/Rosekind_062711.pdf. Accessed October 1, 2013.
- 5 Pruchnicki SA, Wu LJ, Belenky G. An exploration of the utility of mathematical modeling predicting fatigue from sleep/wake history and circadian phase applied in accident analysis and prevention: the crash of Comair Flight 5191. *Accid Anal Prev*. 2011;3(3):1056–1061.
- 6 Koenig RL. Air traffic control counterclockwise rotating shift schedule appears to affect performance only on night shift. *Flight Safety Foundation Airport Operations*. 1997;23(2):1–7.
- 7 Banderet LE, Stokes JW, Francesconi R, Kowal DM, Naitoh P. Artillery teams in simulated sustained combat: performance and other measures. In: Johnson LC, Tepas DJ, Colquhoun WP, Colligan MJ, eds. *Biological Rhythms, Sleep and Shiftwork*. New York: Spectrum; 1981:459–477.
- 8 Landrigan CP, Rothschild JM, Cronin JW, Kaushal R, Burdick E, Katz JT, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med*. 2004;351(18):1838–1848.
- 9 Lockley SW, Cronin JW, Evans EE, Cade BE, Lee CJ, Landrigan CP, et al. Effect of reducing interns' work hours on sleep and attentional failures. *N Engl J Med*. 2004;351(18):1829–1836.
- 10 Belenky G, Hursh SR, Fitzpatrick J, Van Dongen HPA. Split sleeper berth use and driver performance: a review of the literature and application of a mathematical model predicting performance from sleep/wake history and circadian phase. Report prepared for The American Trucking Association. Sleep and Performance Research Center. Spokane, WA: Washington State University; 2008.
- 11 Mollicone DJ, Van Dongen HPA, Dinges DF. Optimizing sleep wake schedules in space: sleep during chronic nocturnal sleep restriction with and without diurnal naps. *Acta Astronaut*. 2007;60:354–361.
- 12 Mollicone DJ, Van Dongen HPA, Rogers NL, Dinges DF. Response surface mapping of neurobehavioral performance: testing the feasibility of split sleep schedules for space operations. *Acta Astronaut*. 2008;63(7–10):833–840.
- 13 Sadeh A, Alster J, Urbach D, Lavie P. Actigraphically based automatic bedtime sleep-wake scoring: validity and clinical applications. *Journal of Ambulatory Monitoring*. 1989;2(3):209–216.
- 14 Reid K, Dawson D. Correlation between wrist activity monitor and electrophysiological measures of sleep in a simulated shiftwork environment for younger and older subjects. *Sleep*. 1999;22(3):378–385.
- 15 Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. The role of actigraphy in the study of sleep and circadian rhythms. *Sleep*. 2003;26(3):342–392.
- 16 Sadeh A, Acebo C. The role of actigraphy in sleep medicine. *Sleep Med Rev*. 2002;6(2):113–124.
- 17 Thorne DR, Johnson DE, Redmond DP, Sing HC, Belenky G, Shapiro JM. The Walter Reed palm-held psychomotor vigilance test. *Behav Res Methods*. 2005;37(1):111–118.
- 18 Lamond N, Jay SM, Dorrian J, Ferguson SA, Roach GD, Dawson D. The sensitivity of a palm-based psychomotor vigilance task to severe sleep loss. *Behav Res Methods*. 2008;40(1):347–352.
- 19 Balkin TJ, Bliese PD, Belenky G, Sing H, Thorne DR, Thomas M, et al. Comparative utility of instruments for monitoring sleepiness-related performance decrements in the operational environment. *J Sleep Res*. 2004;13(3):219–227.
- 20 Lamond N, Dawson D, Roach GD. Fatigue assessment in the field: validation of a hand-held electronic psychomotor vigilance task. *Aviat Space Environ Med*. 2005;76(5):486–489.

- 21 Strauss E, Sherman EMS, Spreen O. *A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary*. New York: Oxford University Press; 2006.
- 22 Gueorguieva R, Krystal JH. Move over ANOVA: progress in analyzing repeated-measures data and its reflection in papers published in the Archives of General Psychiatry. *Arch Gen Psychiatry*. 2004;61(3):310–317.
- 23 Van Dongen HP, Olofsen E, Dinges DF, Maislin G. Mixed-model regression analysis and dealing with interindividual differences. *Methods Enzymol*. 2004;384:139–171.
- 24 Akerstedt T. Shift work and disturbed sleep/wakefulness. *Occup Med (Lond)*. 2003;53(2):89–94.
- 25 Richardson GS, Wyatt JK, Sullivan JP, Orav EJ, Ward AE, Wolf MA, et al. Objective assessment of sleep and alertness in medical house staff and the impact of protected time for sleep. *Sleep*. 1996;19(9):718–726.
- 26 Arora V, Dunphy C, Chang VY, Ahmad F, Humphrey HJ, Meltzer D. The effects of on-duty napping on intern sleep time and fatigue. *Ann Intern Med*. 2006;144(11):792–798.
- 27 Volpp KG, Shea JA, Small DS, Basner M, Zhu J, Norton L, et al. Effect of a protected sleep period on hours slept during extended overnight in-hospital duty hours among medical interns: a randomized trial. *JAMA*. 2012;308(21):2208–2217.