informa
healthcare

Sleep, Sleepiness, Fatigue, and Performance of 12-Hour-Shift Nurses

Jeanne Geiger-Brown,[1] Valerie E. Rogers,[2] Alison M. Trinkoff,[1] Robert L. Kane,[3] R. Barker Bausell,[1] and Steven M Scharf,[4]

[1]*Work and Health Research Center, University of Maryland School of Nursing, Baltimore, Maryland, USA,* [2]*Center for Sleep and Circadian Neurobiology, University of Pennsylvania, Philadelphia, Pennsylvania, USA,* [3]*Neurology Division, University of Maryland School of Medicine, Baltimore, Maryland, USA,* [4]*Pulmonary and Critical Care Division, University of Maryland School of Medicine, Baltimore, Maryland, USA*

Nurses working 12-h shifts complain of fatigue and insufficient/poor-quality sleep. Objectively measured sleep times have not been often reported. This study describes sleep, sleepiness, fatigue, and neurobehavioral performance over three consecutive 12-h (day and night) shifts for hospital registered nurses. Sleep (actigraphy), sleepiness (Karolinska Sleepiness Scale [KSS]), and vigilance (Performance Vigilance Task [PVT]), were measured serially in 80 registered nurses (RNs). Occupational fatigue (Occupational Fatigue Exhaustion Recovery Scale [OFER]) was assessed at baseline. Sleep was short (mean 5.5 h) between shifts, with little difference between day shift (5.7 h) and night shift (5.4 h). Sleepiness scores were low overall (3 on a 1–9 scale, with higher score indicating greater sleepiness), with 45% of nurses having high level of sleepiness (score $\geq$7) on at least one shift. Nurses were progressively sleepier each shift, and night nurses were sleepier toward the end of the shift compared to the beginning. There was extensive caffeine use, presumably to preserve or improve alertness. Fatigue was high in one-third of nurses, with intershift fatigue (not feeling recovered from previous shift at the start of the next shift) being most prominent. There were no statistically significant differences in mean reaction time between day/night shift, consecutive work shift, and time into shift. Lapsing was traitlike, with rare (39% of sample), moderate (53%), and frequent (8%) lapsers. Nurses accrue a considerable sleep debt while working successive 12-h shifts with accompanying fatigue and sleepiness. Certain nurses appear more vulnerable to sleep loss than others, as measured by attention lapses. (Author correspondence: jgeiger@son.umaryland.edu)

Keywords: Attention, Extended work hours, Fatigue, Neurocognition, Nurses, Sleep deprivation, Sleepiness, Vigilance, Work schedule tolerance

INTRODUCTION

Extended work shifts for nurses began to appear in the 1980s and are now nearly ubiquitous in hospital nursing (Josten et al., 2003; Trinkoff et al., 2006a). Although these extended shifts are well liked among nurses, they are not without consequences to the nurses and patients for whom they provide care. Twelve-hour shifts have been associated with increased patient-care errors as well as work-related accidents and injuries, e.g., musculoskeletal disorders, needlestick injuries, and drowsy driving (Novak & Auvil-Novak, 1996; Rogers et al., 2004; Scott et al., 2007; Trinkoff et al., 2006b, 2007). Although these adverse events may be related to high work demands over the long duration of the shift, 12-h shifts also may restrict the opportunity for sleep, which in turn could cause reduced performance. A 12-h shift can actually extend to ≥13 h when time is included for tasks that have to be completed before departure from work, such as intershift report, medication counting, unfinished patient care, and paperwork (Trinkoff et al., 2006a). Additionally, long commutes to/from work plus home responsibilities, such as housework and dependent care, may further limit sleep opportunity (Clissold et al., 2002; Hughes & Rogers, 2004).

Previous studies of extended nursing shifts have shown that nurses report insufficient sleep, poor quality sleep, and fatigue (Chan, 2009; Dorrian et al., 2008; Edell-Gustafsson et al., 2002; Geiger-Brown et al., 2011; Iskra-Golec et al., 1996; Portela et al., 2004; Ruggiero, 2003; Samaha et al., 2007; Surani et al., 2007). However, data on objectively measured sleep duration in nurses have not been often reported. In other occupations

Submitted May 4, 2011, Returned for revision May 28, 2011, Accepted November 28, 2011

This work was performed at the Work and Health Research Center, University of Maryland School of Nursing, Baltimore, Maryland, USA.
Address correspondence to Dr. Jeanne Geiger-Brown, University of Maryland School of Nursing, 655 W Lombard Street, Suite 575, Baltimore, MD 21201, USA. Tel.: 410-706-5368; Fax: 410-706-0253; E-mail: jgeiger@son.umaryland.edu

when shifts were lengthened from 8 to 12 h, the opportunity to sleep between shifts was reduced (Bendak, 2003; Tucker et al., 1996). Although there is no definitive cut-point to determine how much sleep is sufficient for any individual (Dawson & McCulloch, 2005; Zhou et al., 2010), increases in sleepiness and declines in neurobehavioral performance appear once time in bed for a single night decreases to <5–6 h. Controlled laboratory studies have demonstrated that when reduced time in bed continues over multiple nights, there is progressive neurobehavioral impairment for each night of sleep restriction (Fafrowicz et al., 2010; van Dongen et al., 2003). This is relevant to nursing, as many nurses choose to work several 12-h shifts in a row to accrue a string of consecutive off days (Surani et al., 2007). If 12-h shifts limit sleep opportunity, then the resulting sleep deficiency could lead to corresponding deficits in neurobehavioral performance and increased risk for occupational injuries and errors (Lombardi et al., 2010; Swaen et al., 2003; Trinkoff et al., 2006b, 2007). Fatigue and sleep deficiency may increase the risk for other health conditions, including cardiovascular and cerebrovascular diseases, e.g., hypertension and stroke, and metabolic changes, e.g., glucose dysregulation, metabolic syndrome, and obesity (Chen et al., 2010; Knutson, 2010; Tanaka et al., 2010). Currently, there are few studies documenting actual sleep patterns in nurses working successive 12-h shifts. The purpose of this study was to describe patterns of achieved sleep, sleepiness, occupational fatigue, and neurobehavioral performance (lapses, anticipations, reaction time, and variability in responding) over three consecutive shifts for hospital registered nurses. We hypothesized that total sleep time would be shorter between shifts than before and after a block of 12-h shifts, and that sleepiness would increase and reaction times would slow on successive worked shifts.

METHODS

Sample and Data Collection Procedures

Female registered nurses providing full-time (≥36 h/wk) direct patient care on medical-surgical and critical care units were recruited from a large US hospital through advertising flyers and researcher attendance at nursing staff meetings. Sampling was stratified to achieve equal representation of day- and night-shift nurses. A 10-min telephone interview was conducted to screen potential participants (N = 175), excluding nurses with acute stressors in the past 12 mos as well as those using sedating or activating medications (hypnotics, opioid analgesics, stimulants) ≥3 d/wk, or with previously diagnosed sleep disorders (N = 37). Acute stressors included death of spouse or close relative or friend, marital separation or divorce, new baby, or deteriorated financial condition. In order to participate, study nurses were required to have an upcoming schedule with three or more consecutive 12-h shifts preceded by two off days; 58 nurses were screened and eligible, but their work schedule did not conform to this protocol during the data collection period. Thus, the total enrollment was 80 participants. Data collection began on the off day immediately prior to starting their work schedule and continued through the sleep period after the third work shift. These three consecutive shifts were either day or night shift; no rotation occurred during the three days of measurement. The University of Maryland School of Medicine Institutional Review Board approved this protocol, which was conducted in accordance with the international ethical standards for human biological rhythm research (Portaluppi et al., 2010).

Study Measures

Actigraphy

Sleep was measured with a wrist-worn actigraph (Actiwatch Score; Philips Respironics, Bend, OR, USA). Actigraphy is a reliable and valid measure for detecting sleep in normal, healthy adult populations (Littner et al., 2003), and has been used to study sleep/wake patterns for more than 30 yrs (Ancoli-Israel et al., 2003). Individual sleep periods were calculated from actigraphically determined sleep onset to actigraphically determined sleep offset, with correction for wake after sleep onset. Total sleep time was the sum, in minutes, of all periods scored as sleep periods in a 24-h day, including naps. Data were recorded using 1-min epochs and scored using the default settings of the actigraphy scoring algorithm (Respironics, 2005).

Sleep/Activity Diary

Start and end times for sleep periods were corroborated with data recorded in an activity/sleep diary. Nurses were instructed to record the start and end times of all sleep periods, including naps. Caffeine use was measured by having the nurse record in the diary the number of ounces of caffeinated beverages that she consumed during work or the commute to/from work, and during non-work time.

Karolinska Sleepiness Scale (KSS)

Sleepiness was measured using the KSS (Åkerstedt & Gillberg, 1990), a single-item measure of sleepiness (1 = "very alert" to 9 = "very sleepy-great effort to keep awake, fighting sleep"). The KSS is the standard measure of sleepiness in occupational studies of performance, and has demonstrated validity with electroencephalograph assessment (Torsvall et al., 1989). Participants recorded their level of sleepiness into the Actiwatch Score at the beginning of their shift and every 2 h thereafter throughout their shift in response to a cue (actigraph beep), for a maximum of 7 KSS scores/shift. For this study, a high level of sleepiness during the shift was defined as a score ≥7 (upper one-third of the scale range) (Åkerstedt & Gillberg, 1990).

Occupational Fatigue Exhaustion Recovery scale (OFER)

Fatigue was measured at baseline using the OFER (Winwood et al., 2005). This 15-item scale has three subscales that measure acute, chronic, and intershift fatigue on a 0–100 scale. The OFER has been validated in a sample of registered nurses, with test-retest reliabilities ranging from .62 to .84 for the subscales. A higher OFER score indicates more fatigue. For this study, a score of ≥80 points was defined as a high level of fatigue (upper one-fifth of the scale range).

Neurobehavioral Tests

Neurobehavioral function was assessed using the Walter Reed Psychomotor Vigilance Test (PVT), a portable reaction time test based on the Dinges and Powell digital test (Thorne et al., 2005). The Walter Reed PVT has been shown to be sensitive to sleep deprivation and circadian effects (Thorne et al., 2005). The PVT was administered on a palmtop computer using a 5-min test with 50 possible responses to randomly spaced stimuli per test. Four indicators of neurobehavioral functioning were measured per session: lapses, anticipations, mean reaction time, and variability in responses (i.e., standard deviation of reaction time). Lapses were defined as those responses >500 ms. Anticipations were responses prior to presentation of the stimulus (false starts). Testing was performed at the beginning and end of each 12-h shift.

All participants came to the research laboratory to complete baseline questionnaires and a 2-h training session on use of the equipment. Two observed practice sessions on the PVT and KSS scoring were completed during training to ensure competence in their self-administration.

Data Analysis

Demographic and response variables were described based on level of measurement. Caffeine use was described in the subsample that consumed caffeinated beverages using the median number of ounces consumed per day. Mean and standard deviations were calculated for OFER subscales. Total sleep time (TST) was assessed for the main sleep period preceding the first 12-h shift, and for the sleep period occurring after the next three 12-h shifts.

A linear mixed model was used to compare differences in TST between study days. Marginal means for sleepiness were estimated by consecutive work shift, day/night shift, and hour into shift using maximum likelihood, with assessment of main and 2-way interaction effects. PVT lapsing and anticipations were analyzed using a generalized estimating equation (GEE) with negative binomial distribution and log link due to the overdispersed Poisson distribution of the data. Marginal means were computed for consecutive shift (first, second, third), shift type (day, night), and time into shift (beginning, end), assessing main and 2-way interaction effects. A similar GEE approach was used to examine mean reaction time (using gamma distribution) and standard deviations (Poisson distribution) around the mean. Within-subject heterogeneity of lapse patterns over the three 12-h shifts was assessed using a growth mixture model (MPlus, version 4.1; Mplus, Muthén & Muthén, Los Angeles, CA), with selection of the best-fitting latent class solution using customary fit parameters, including Akaike information criteria (AIC), Bayes information criteria (BIC), adjusted BIC, entropy, and the Lo-Mendel-Rubin test (Nylund et al., 2007). Additional analyses examined the effect of contextual variables on TST and fatigue, including age, marital status, childcare, second job, and student status, using correlations or tests of mean difference as appropriate to the level of measurement.

RESULTS

Subject ages ranged from 23 to 64 yrs, with mean age being 37 yrs. On average, they had 10 yrs of nursing experience. In addition to their full time job, about one-third provided care to children or elders at home (Table 1), and 12% worked a second job for compensation (median: 28 h/mo). Nearly half were overweight or obese, but few nurses smoked. For the 87% of nurses who used caffeinated beverages, the median number of ounces consumed per day over the four study days was 16.

TST by study day for the full sample is shown in Figure 1. On the day prior to the first 12-h shift, some nurses slept as long as 15 h, with an average of 5.9 (SD = 1.0) h for day-shift nurses and 9.1 (2.0) h for night-shift nurses ($t = 8.8$, $p < .001$). Napping, which is included in the TST, was recorded in 73% of night-shift nurses before their first shift. TST between 12-h shifts was short for both day- and night-shift nurses. The mean TST following the first 12-h work shift was 5.7 (SD = .9) and 5.2 (1.2) h for day- and night-shift nurses, respectively ($t = 2.07$, $p = .042$ for significant difference in TST between shifts), and following the second 12-h shift was 5.7 (.7) and 5.5 (1.1) h, respectively ($p > .05$). On average, intershift sleep was 2 h shorter than sleep on the day prior to the first shift (mean difference 125 min, standard error [SE] = 17 min, $p < .001$). Sleep after the third shift was 40 min longer than sleep between shifts (SE = 17 min, $p = .02$), being longer for day-shift nurses, 7.3 (1.9) h, than for night-shift nurses, 5.1 (2.3) h ($t = 4.3$, $p < .001$).

Mean scores on the KSS were higher for each consecutive work shift, 2.9 (SD = .16), 3.0 (.15), and 3.3 (.18), respectively, for the first, second, and third work shifts ($\chi^2 = 13.6$, $p < .001$). There was also a significant increase in sleepiness by hour into the shift, with mean KSS scores at the beginning of the work shift of 2.7 (.15), dipping at the second hour to 2.3 (.13), and then increasing linearly to 3.9 (.21) by the 12th hour ($\chi^2 = 136.3$, $p < .001$). Night-shift nurses showed greater sleepiness towards the end of the work shift compared to day-shift nurses (shift by hour interaction, $\chi^2 = 25.4$, $p < .001$) (Figure 2A). Sleepiness by hour into shift was higher for most of the third work shift compared to the first two work shifts (day by hour interaction, $\chi^2 = 30.1$, $p = .008$), shown in Figure 2B. Although

TABLE 1. Characteristics of the sample, female full-time hospital nurses working three 12-h shifts (N = 80)

Characteristics	N (%) Range
Age, yrs; mean (± SD), range	37.2 (± 10.4), 23–64
Ethnicity (% Hispanic)	2 (2.5)
Race	
White	47 (58.8)
Black	12 (15.0)
Asian	20 (25.0)
American Indian, Alaska native	1 (1.3)
Marital status	
Never married	33 (41.3)
Married	34 (42.5)
Separated or divorced	11 (13.8)
Widowed	2 (2.5)
Children at home	23 (28.8)
Providing eldercare	2 (2.5)
Student	17 (21.3)
Working second job	10 (12.5)
Years RN; mean (± SD), range	9.7 (± 9.7), 5–40
Years current job; mean (± SD), range	4.3 (± 5.7), 5–28
Shift usually worked	
Permanent day	21 (26.6)
Permanent night	32 (40.5)
Rotating	17 (21.5)
Other	9 (11.4)
Shift this study	
Day	39 (48.8)
Night	41 (51.5)
Current smoker	4 (5.0)
Caffeinated beverage (ounces)/medians	14–19
Body mass index	
Normal (BMI <25 kg/m^2)	42 (52.5)
Overweight (BMI 25–29.9 kg/m^2)	25 (31.3)
Obese (BMI ≥30 kg/m^2)	13 (16.3)

sleepiness scores were in the low range of KSS scale values, a high level of sleepiness (upper one-third of scale) occurred at least once over the three study shifts in 45% of the nurses. One in four night-shift nurses had a high level of sleepiness at 07:00 h, the time they were leaving work to drive home.

Occupational fatigue levels showed wide variation in the pooled sample of night- and day-shift nurses, with intershift fatigue having the highest mean score (mean = 60.1, SD = 19.5, range 10-97), followed by acute fatigue (mean = 52.1, SD = 21.3, range 7–90) and chronic fatigue (mean = 31.5, SD = 20.3, range 0–80). Baseline intershift fatigue was higher for night-shift nurses (mean = 63.7, SD = 17.8) than for day-shift nurses (mean = 56.3, SD = 20.7), with the mean difference approaching significance ($t = 1.7$, $p = .09$). Thirty-six percent of the nurses had a high level of fatigue on one or more of the OFER subscales.

Results from the PVT parameters by day/night shift, consecutive work shift, and time into shift are shown in Table 2. During a 5-min PVT testing session, 20.8% of tests showed no lapses, 34.6% 1–2 lapses, and 10% ≥10 lapses. Nurses showed overall differences in lapsing over successive work shifts ($\chi^2 = 9.04$, $p = .01$), with a mean of 3.2 (SD = .7) lapses for the first, 4.1 (.6) for the second, and 3.6 (.5) for the third study day.

Latent class analysis of nurses by pattern of lapsing at the end of the shift over the three work shifts is shown in Figure 3. Nurses fell into three classes of lapsers based on class probabilities for the best fitting solution, i.e., rare (39%), moderate (53%), and frequent (8%) lapsers. Anticipation responses to PVT stimulus showed 75% of tests having 0–2 false starts, and the highest 10% showing 5–27 false starts. The difference in anticipations between the day shift and night shift was not significant; however, mean anticipations by time into shift increased from the beginning (mean = 1.6, SD = .3) to the end of the shift (mean = 2.0, SD = .2), ($\chi^2 = 3.99$, $p = .04$). There were no statistically significant differences in mean reaction time between day/night shift, consecutive work shift, or time into shift.

Some contextual factors did influence sleep and fatigue. Nurses who worked second jobs had longer sleep prior to the first shift (592 vs. 439 min, $t = 3.1$, $p = .01$), but showed no significant differences in sleep between shifts. Intershift fatigue was higher in nurses who were divorced/separated (mean = 72.4, SD = 18.6) or widowed (mean = 75.0, SD = 16.4) than in nurses who were married (mean = 60.4, SD = 14.1) or single (mean = 54.8, SD = 22.9) ($F = 2.9$, $p = .04$), and although single nurses were also younger, this did not alter the association of marital status to intershift fatigue.

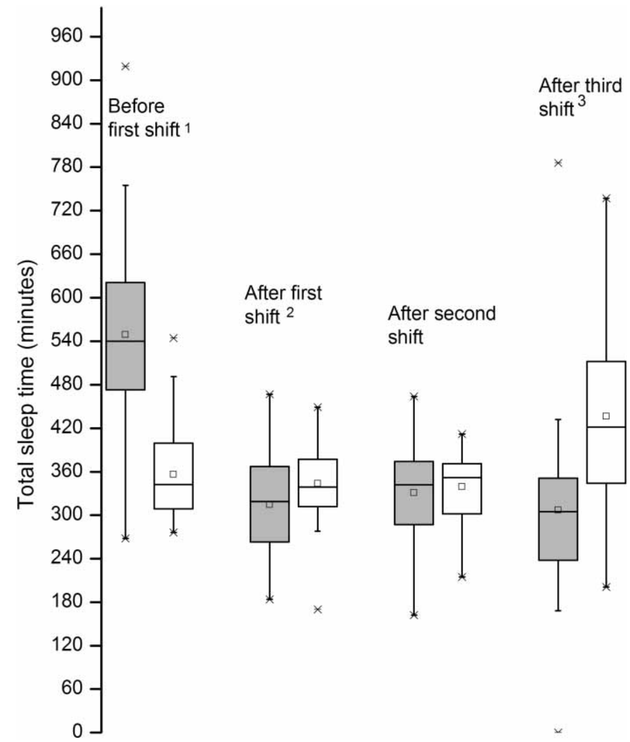

FIGURE 1. Total sleep time (minutes) for day- and night-shift nurses working three successive 12-h shifts. Shaded box plots for nurses working night shift, nonshaded boxes for day shift. Box plot contains 25th to 75th percentiles, with central line as median and small box as mean, whiskers are to 95th percentile, and crosses are outliers. Differences between day-shift versus night-shift sleep. [1]$t = 8.8$, $p < .0012$; [2]$t = -2.1$, $p = .04$; [3]$t = -4.3$, $p < .001$.

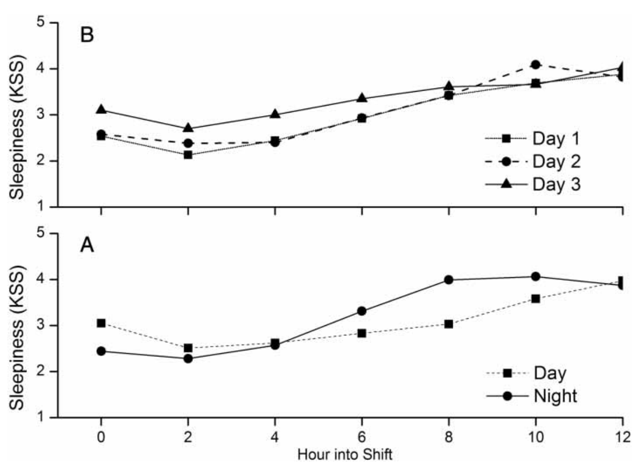

FIGURE 2. Sleepiness (KSS) by hour into shift, study day, and shift. (A) Sleepiness (KSS) by hour into shift for nurses working the day shift (dotted line) and night shift (solid line). (B) Sleepiness (KSS) by hour into shift for nurses on the 1st (solid line, square data point), 2nd (dotted line, circle data point), 3rd (solid line, triangle data point) 12-h work periods.

DISCUSSION

The main finding of our study is that nurses working successive 12-h work shifts achieve an inadequate amount of sleep between shifts to recover physically or cognitively, irrespective of whether they work the day or the night shift. Nurses experienced greater sleepiness by their third consecutive 12-h shift than during their first two shifts of work, and night nurses appeared to be particularly vulnerable to sleepiness by the end of their work shift compared to day nurses. Neurobehavioral testing during actual work conditions has rarely been performed in nurses. In our study, errors measured by anticipation responses on a validated measure of neurobehavioral functioning were committed more frequently after working for 12 consecutive hours than they were when nurses were fresh at the beginning of their shift. Furthermore, over one-third of nurses reported high levels of fatigue, with intershift fatigue being the most prominent type of fatigue.

In this sample, the majority of nurses had short sleep (<6 h) between shifts. The narrow range of variation in sleep times, with sleep extension on off days, suggests that this pattern of short sleep may be due to a lack of sleep opportunity rather than to sleep ability (Roehrs et al., 1996). This finding is consistent with American Time Use Survey finding that sleep time is exchanged for work and commuting hours in a linear relationship, even after adjustment for contextual factors (Basner et al., 2007). The very high range of TST levels on the day before the first 12-h shift may reflect continued recovery sleep from prior 12-h shift sleep loss or sleep banking in anticipation of sleep loss between 12-h shifts, particularly for nurses working second jobs. Nevertheless, our data are consistent with the study by Luckhaupt et al. (2010) showing that short sleep is common among health care workers, a finding common among several other studies wherein nurses report insufficient or poor quality sleep (Geiger-Brown et al., 2011). Our finding of objectively measured sleep deficiency among nurses working 12-h shifts supports the finding of subjectively reported short sleep in other studies where an association with increased risk of injury was reported (e.g., Lombardi et al., 2010; Ohayon et al., 2010). For example, in the National Health Interview Study, sleep <5 h more than doubled the risk for workplace injury (odds ratio [OR] 2.65), and sleep of 5–5.9 h nearly doubled the risk for injury (OR 1.79) compared to ≥7 h sleep (Lombardi et al., 2010). Trinkoff and colleagues (2006b, 2007) found an increase in needlestick injuries and musculoskeletal disorders among nurses working 12-h shifts. The risk for patient-care errors and near errors was increased in two studies of 12-h-shift nurses (Rogers et al., 2004; Scott et al., 2006), and was associated with shorter sleep in another (Dorrian et al., 2006). Moreover, the risk for drowsy driving, which increases the possibility of motor vehicle accidents on the drive home after work, was demonstrated by Scott et al. (2007) to be increased after working 12-h shifts.

There are serious implications to our findings of short sleep in 12-h-shift nurses. If the sleep deprivation we recorded is a recurrent pattern, as we suspect it is, these full-time nurses are getting little sleep between shifts

TABLE 2. Estimated marginal means for neurobehavioral parameters by study day, shift, and time into shift

	No. lapses		No. anticipations		Mean reaction time		SD of reaction time	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Shift								
Day	3.1	.7	1.8	.2	290.6	10.7	125.8	16.3
Night	3.9	.8	1.8	.4	306.4	10.9	161.8	16.4
Study day								
1st	3.2	.7	1.8	.3	294.5	9.0	149.0	18.9
2nd	4.1	.6	1.7	.2	303.0	8.5	145.4	14.9
3rd	3.6	.5	1.9	.3	297.7	7.6	134.2	13.0
Time into shift								
Beginning	3.5	.6	1.6	.3	294.5	9.0	136.0	12.2
End	3.7	.5	2.0	.2	297.7	7.6	149.7	15.4
Test of model effects	χ^2 (*df*)	*p*	χ^2 (*df*)	*p*	χ^2 (*df*)	*p*	χ^2 (*df*)	*p*
Shift	.74 (1)	.39	.20 (1)	.89	1.06 (1)	.30	2.34 (1)	.13
Study day	9.04 (2)	.01	1.14 (2)	.57	3.13 (2)	.21	.81 (2)	.67
Time into Shift	.18 (1)	.67	3.99 (1)	.04	1.74 (1)	.19	.89 (1)	.35
Shift × Day	1.01 (2)	.60	3.82 (2)	.15	2.60 (2)	.27	3.67 (2)	.16
Shift × Time into Shift	1.09 (1)	.30	1.07 (1)	.30	.98 (1)	.32	.18 (1)	.67
Day × Time into Shift	1.80 (2)	.41	2.84 (2)	.30	1.74 (2)	.42	2.77 (2)	.25

for 8–10 d/mo or more, possibly over a career spanning ≥20 yrs. Available data indicate that this could put them at increased risk for cardiovascular disease, such as hypertension and stroke, and impaired glucose metabolism (Grandner et al., 2010). The finding that many of our cohort were already overweight or obese increases this risk.

A surprising finding was that sleepiness was unexpectedly low for the level of sleep deficit identified (Åkerstedt & Kecklund, 2010; Silva et al., 2010); yet, our sample included many nurses <45 yrs when sleep deficiency often produces sleepiness (Duffy et al., 2009). This may be partially due to amplified alertness by the liberal use of caffeine. Additionally, the social context on the units where the data were gathered may have reduced nurses' sleepiness (Åkerstedt, 2008). Nurses often move about during the night shift and have social interactions to keep themselves awake. Nevertheless, we found a progressive increase in sleepiness with failure to return to baseline between work days, with one-fourth of night nurses having high sleepiness at the time they were preparing to drive home, as well as episodic high levels of sleepiness and high intershift fatigue. These findings point to an accruing sleep debt, and potential failure to accurately perceive impaired performance resulting from chronic sleep loss among some nurses. Drowsy driving is of particular concern, since they may be overconfident in their ability to drive safely (Jones et al., 2006).

Not only did nurses in our study exhibit sleep deprivation, but also their neurobehavioral tests demonstrated some performance problems. Although there are few data documenting neurobehavioral changes under actual work conditions in professional nurses, a study of police officers showed increased lapsing on a 5-min PVT with shorter sleep duration and longer time since sleep (Neylan et al., 2010). In our study, the increasingly frequent lapsing during performance on the PVT on the second day compared to the first day of work suggests that limited sleep between shifts is affecting performance by producing more frequent episodes of inattention, a well-known effect of sleep loss. Some of these lapses likely represent microsleep episodes (Anderson et al., 2010). Although sleep deprivation has been shown to reduce vigilance and attention (Banks & Dinges, 2007; Gander et al., 2008; Lim & Dinges, 2008; van Dongen & Dinges, 2006), others have shown that there are significant interindividual differences in sensitivity to sleep loss (Axelsson et al., 2008; van Dongen, 2006), as we also demonstrated. Our finding of three latent classes of lapsing (rare, occasional, and frequent) provides further validation of these interindividual differences. The magnitude of the differences in lapsing over consecutively worked shifts and of anticipations over the duration of the shifts was small, and we believe that this may be partly due to nurses' reliance on caffeine to preserve alertness and mental performance. Exploration of a genetic basis for interindividual variations in tolerance to sleep loss could be important for identifying persons who may be less well suited to working shifts involving extended hours, particularly for professionals in safety-sensitive professions such as nursing.

The study should be interpreted with consideration of its strengths and limitations. Strengths of this study included our use of actigraphy to objectively estimate achieved sleep rather than relying on subjective self-reported sleep. Neurobehavioral performance was also measured using an objective, well-validated test, the PVT. However, there were a few limitations to this study. Our study did not capture sleep data over the course of ≥7 d, so we were not able to assess the potential for sleep deficiency over longer periods in nurses working second jobs. Testing under real-life conditions

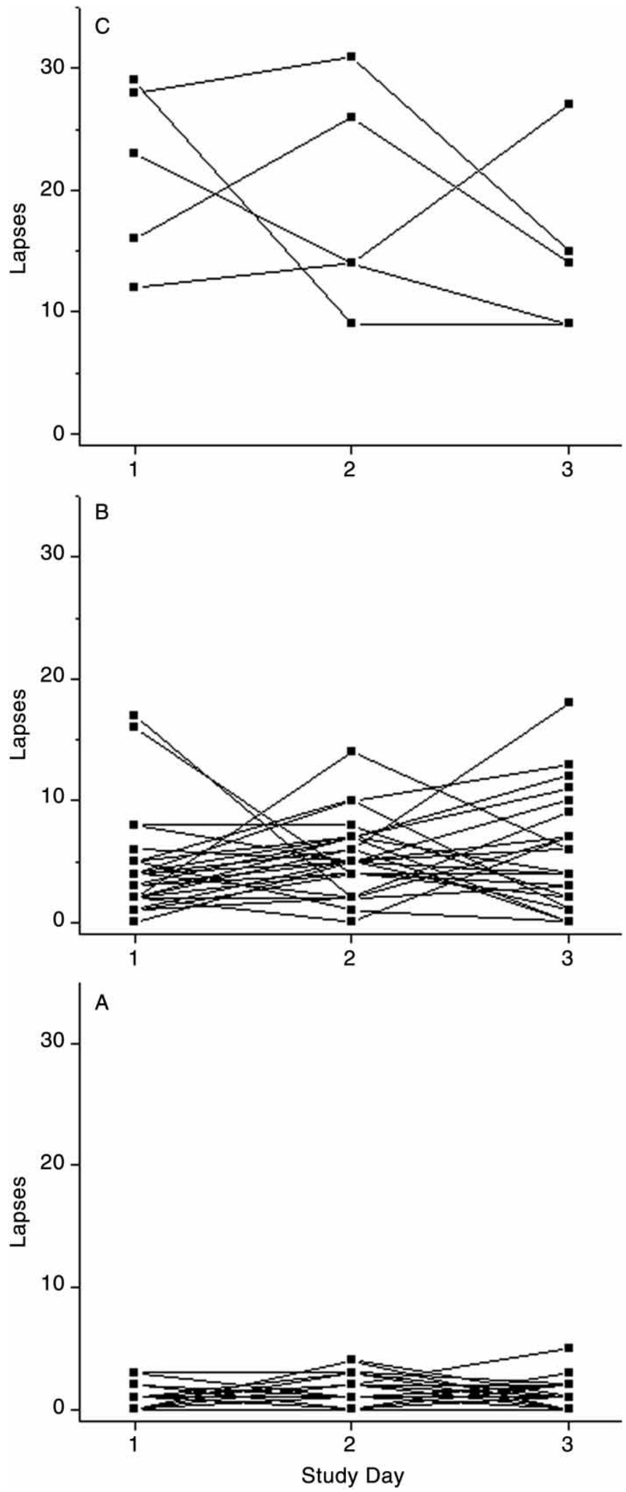

FIGURE 3. End-of-shift PVT lapses over 5-min test categorized into three latent classes: (A) rare lapsers; (B) moderate lapsers; (C) frequent lapsers. Each line represents the lapse pattern over the three study days for individual participant.

in occupational settings is, by its nature, unable to be as tightly controlled as is experimental research on sleep loss conducted in laboratory settings; thus, there is likely to be some measurement error in PVT scores due to environmental distractions. The 5-min PVT test used by our nurses is slightly less sensitive to sleep deprivation than the standard 10-min test (Roach et al., 2006); however, the shorter test was necessary due to time constraints of testing during duty hours in a hospital setting. In addition, there are no studies that describe the ecological validity of the PVT to professional nursing performance; however, vigilance is the substrate upon which all higher-level functions depend, so a loss of vigilance is assumed to produce impaired performance.

KSS scores entered into an Actiwatch Score on cue has not been validated as a method of capturing these data, and the potential biasing effect of this novel approach is unknown. All of the nurses were female, so we cannot generalize to the 8% of registered nurses that are male. There may be differences in sleep among male compared to female nurses due to their disparate social and family roles, as well as physiological differences compared to women, such as hormonal changes related to menstruation or menopause, which may affect sleep. This sample of nurses was slightly younger than the overall US registered nurse population (median age 35 vs. 46 yrs, respectively), more racially diverse (59% vs. 83% Caucasian), less likely to be married (42% vs. 74%), and less likely to be providing child or elderly dependent care at home (30% vs. 55%) (Health Resources and Services Administration, 2010), which is typical for hospital staff nurses compared to nurses overall. We did not have data about specific schedule patterns for nurses working at this hospital. Subsequent to this study, however, schedules at the hospital were regulated so as not to exceed four consecutive 12-h shifts. Work schedules prior to the off days that initiated our data collection period were not measured. Our requirement of two off days prior to the start of the three consecutive work shifts measured in our study may not have been sufficient to recover from prior shifts, and there may be differences in nurses' fatigue due to prior shifts (night vs. day, extended consecutive shifts, or second job schedules) during this unmeasured period.

The Institute of Medicine (2004) proposed specific hours-of-service limits on nursing hours, recommending that nurses work no more than 12 h/d. Our data suggest that even these guidelines will lead to a considerable sleep deficit in nurses. We have particular concerns about 12-h night shifts where inadequate sleep combines with the circadian low to produce drowsiness during the drive home from work. Future studies should be directed at better delineating outcomes of various patterns of extended shiftwork and improving safety, performance, and health outcomes of nurses working these shifts. There is a compelling need to develop methods to assess fitness for duty when sleep is curtailed, and to assist nurses whose biologic disposition makes them highly sensitive to sleep deprivation, with possible subsequent impaired performance. In addition, improving the quantity and quality of sleep for all 12-h nurses should be a priority, including implementing educational and scheduling interventions, as well as planned napping for those working these demanding schedules.

ACKNOWLEDGMENTS

Funding for this work was from the National Institute for Occupational Safety and Health, R21OH008392 (Dr. Geiger-Brown, principal investigator [PI]), and the National Institutes of Health, National Center for Research Resources, 1K12RR023250 (Dr. Alan Shuldiner, PI; Dr. Geiger-Brown, awardee)

Declaration of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

REFERENCES

Åkerstedt T, Gillberg M. (1990). Subjective and objective sleepiness in the active individual. *Int. J. Neurosci.* 52:29–37.

Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollack C. (2003). The role of actigraphy in the study of sleep and circadian rhythms. *Sleep* 26:342–392.

Anderson C, Wales AW, Horne JA. (2010). PVT lapses differ according to eyes open, closed, or looking away. *Sleep* 33:197–204.

Banks S, Dinges DF. (2007). Behavioral and physiological consequences of sleep restriction. *J. Clin. Sleep Med.* 3:519–528.

Basner M, Fomberstein KM, Razavi FM, Banks S, William JH, Rosa RR, Dinges DF. (2007). American time use survey: sleep time and its relation to waking activities. *Sleep* 30:1085–1095.

Bendak S. (2003). 12-h workdays: current knowledge and future directions. *Work Stress* 17:321–336.

Chan MF. (2009). Factors associated with perceived sleep quality of nurses working on rotating shifts. *J. Clin. Nurs.* 18:285–293.

Chen J-D, Lin Y-C, Hsiao S-T. (2010). Obesity and high blood pressure of 12-hour night shift female clean-room workers, *Chronobiol. Int.* 27:334–344.

Clissold G, Smith P, Accutt B, Di Milia L. (2002). A study of female nurses combining partner and parent roles with working a continuous three-shift roster: the impact on sleep, fatigue and stress. *Contemp. Nurse* 12:294–302.

Dawson D, McCulloch K. (2005). Managing fatigue: it's about sleep. *Sleep Med. Rev.* 9:365–380.

Dorrian J, Tolley C, Lamond N, van den Heuvel C, Pincombe J, Rogers AE, Dawson D. (2008). Sleep and errors in a group of Australian hospital nurses at work and during the commute. *Appl. Ergon.* 39:605–613.

Edell-Gustafsson UM, Kritz EI, Bogren IK. (2002). Self-reported sleep quality, strain and health in relation to perceived working conditions in females. *Scand. J. Caring Sci.* 16:179–187.

Fafrowicz M, Oginska H, Mojsa-Kaja, Marek T, Golonka K, Tucholsak K. (2010). Chronic sleep deficit and performance of a sustained attention task—an electrooculography study. *Chronobiol. Int.* 27:934–944.

Geiger-Brown, J., Trinkoff AM., Rogers, VE. (2011). The impact of work schedules, home, and work demands on self-reported sleep in registered nurses. *J. Occup. Environ. Med.* 53:303–307.

Grandner MA, Hale L, Moore M, Patel NP. (2004). Mortality associated with short sleep duration: the evidence, the possible mechanisms, and the future. *Sleep Med. Rev.* 14:191–203.

Health Resources and Services Administration, US Department of Health and Human Services. (2010). The Registered Nurse Population. Findings from the 2008 National Sample Survey of Registered Nurses. Accessed on May 1, 2011 from http://bhpr.hrsa.gov/healthworkforce/rnsurveys/rnsurveyfinal.pdf.

Hughes RG, Rogers AE. (2004). Are you tired? *Am. J. Nurs.* 104:36–38.

Institute of Medicine. (2004). *Keeping patients safe: transforming the work environment of nurses*. Washington, DC: Institute of Medicine, Committee on the Work Environment for Nurses and Patient Safety, Board on Health Care Services; Page A (ed.).

Iskra-Golec I, Folkard S, Marek T, Noworel C. (1996). Health, well-being and burnout of ICU nurses on 12- and 8-hour shifts. *Work Stress* 10:251–256.

Josten EJ, Ng-A-Tham JE, Thierry H. (2003). The effects of extended workdays on fatigue, health, performance and satisfaction in nursing. *J. Adv. Nurs.* 44:643–652.

Knutson, KL. (2010). Sleep duration and cardiometabolic risk: a review of the epidemiologic evidence [review]. *Best Pract. Res. Clin. Endocrinol. Metab.* 24:731–743.

Lim J, Dinges DF. (2008). Sleep deprivation and vigilant attention. *Ann. N. Y. Acad. Sci.* 1129:305–322.

Littner M, Kushida CA, Anderson WM, Bailey D, Berry RB, Davila DG, Hirshkowitz M, Kapen S, Kramer M, Loube D, Wise M, Johnson SF. (2003). Practice parameters for the role of actigraphy in the study of sleep and circadian rhythms: an update for 2002. *Sleep* 26:337–341.

Lombardi DA, Folkard S, Willetts JL, Smith GS. (2010). Daily sleep, weekly working hours, and risk of work-related injury: US national health interview survey (2004–2008). *Chronobiol. Int.* 27:1013–1030.

Luckhaupt SE, Tak S, Calvert GM. (2010). The prevalence of short sleep duration by industry and occupation in the national health interview survey. *Sleep* 33:149–159.

Novak RD, Auvil-Novak SE. (1996). Focus group evaluation of night nurses shiftwork difficulties and coping strategies. *Chronobiol. Int.* 13:457–463.

Nylund KL, Asparouhov T, Muthén B. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling. A Monte Carlo simulation study. *Struct. Equat. Model.* 14:535–569.

Ohayon MM, Smolensky MH, Roth T. (2010). Consequences of shiftworking on sleep duration, sleepiness, and sleep attacks. *Chronobiol. Int.* 27:575–589.

Portaluppi F, Smolensky MH, Touitou Y. (2010). Ethics and methods for biological rhythm research on animals and human beings. *Chronobiol. Int.* 27:1911–1929.

Portela LF, Rotenberg L, Waissmann W. (2004). Self-reported health and sleep complaints among nursing personnel working under 12 h night and day shifts. *Chronobiol. Int.* 21:859–870.

Roehrs T, Shore E, Papineau K, Rosenthal L, Roth T. (1996). A two-week sleep extension in sleepy normals. *Sleep* 19:576–582.

Rogers AE, Hwang WT, Scott LD, Aiken LH, Dinges DF. (2004). The working hours of hospital staff nurses and patient safety. *Health Affairs* 23:202–212.

Ruggiero JS. (2003). Correlates of fatigue in critical care nurses. *Res. Nurs. Health* 26:434–444.

Samaha E, Lal S, Samaha N, Wyndham J. (2007). Psychological, lifestyle and coping contributors to chronic fatigue in shiftworker nurses. *J. Adv. Nurs.* 59:221–232.

Scott LD, Hwang WT, Rogers AE, Nysse T, Dean GE, Dinges DF. (2007). The relationship between nurse work schedules, sleep duration, and drowsy driving. *Sleep* 30:1801–1807.

Scott LD, Rogers AE, Hwang WT, Zhang Y. (2006). Effects of critical care nurses' work hours on vigilance and patients' safety. *Am. J. Crit. Care* 15:30–37.

Silva EJ, Wang W, Ronda JM, Wyatt JK, Duffy JF. (2010). Circadian and wake-dependent influences on subjective sleepiness, cognitive throughput, and reaction time performance in older and young adults. *Sleep* 33:481–490.

Surani S, Murphy J, Shah A. (2007). Sleepy nurses: are we willing to accept the challenge today? *Nurs. Adm. Q.* 31:146–151.

Swaen GM, Van Amelsvoort LG, Bultmann U, Kant IJ. (2003). Fatigue as a risk factor for being injured in an occupational accident: results from the Maastricht Cohort Study. *Occup. Environ. Med.* 2003;60(Suppl 1):88–92.

Tanaka K, Sakata K, Oishi M, Morimoto H, Nakada S, Uetani M, Nogawa, Suwazono Y. (2010). Estimation of the benchmark duration of shiftwork associated with weight gain in male Japanese workers. *Chronobiol. Int.* 27:1895–1910.

Thorne DR, Johnson DE, Redmond DP, Sing HC, Belenky G, Shapiro JM. (2005). The Walter Reed palm-held psychomotor vigilance test. *Behav. Res. Methods* 37:111–118.

Torsvall L, Åkerstedt T, Gillander K, Knutsson A. (1989). Sleep on the night shift: 24-hour EEG monitoring of spontaneous sleep/wake behavior. *Psychophysiology* 26:352–358.

Trinkoff A, Geiger-Brown J, Brady B, Lipscomb J, Muntaner C. (2006a). How long and how much are nurses now working? *Am. J. Nurs.* 106:60–71.

Trinkoff AM, Le R, Geiger-Brown J, Lipscomb J, Lang G. (2006b). Longitudinal relationship of work hours, mandatory overtime, and on-call to musculoskeletal problems in nurses. *Am. J. Ind. Med.* 49:964–971.

Trinkoff AM, Le R, Geiger-Brown J, Lipscomb J. (2007). Work schedule, needle use, and needlestick injuries among registered nurses. *Infect. Control Hosp. Epidemiol.* 28:156–164.

Tucker P, Barton J, Folkard S. (1996). Comparison of eight and 12 hour shifts: impacts on health, wellbeing, and alertness during the shift. *Occup. Environ. Med.* 53:767–772.

Van Dongen HP. (2006). Shift work and inter-individual differences in sleep and sleepiness. *Chronobiol. Int.* 23:1139–1147.

Van Dongen HP, Dinges DF. (2005). Sleep, circadian rhythms, and psychomotor vigilance. *Clin. Sports Med.* 24:237–249.

Van Dongen HP, Maislin G, Mullington JM, Dinges DF. (2003). The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep* 26:117–126.

Winwood PC, Winefield AH, Dawson D, Lushington K. (2005). Development and validation of a scale to measure work-related fatigue and recovery: the Occupational Fatigue Exhaustion/Recovery scale (OFER). *J. Occup. Environ. Med.* 47:594–606.

Zhou X, Ferguson SA, Matthews RW, Sargent C, Darwent D, Kennaway DJ, Roach GD. (2010). Interindividual differences in neurobehavioral performance in response to homeostatic sleep pressure. *Chronobiol. Int.* 27:911–921.