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Sleep, fatigue and alertness during working hours among rotating-shift nurses in Korea: An observational study

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Abstract

Aims: To determine the effects of sleep parameters and fatigue on the decline in alertness of nurses across shifts.

Background: Shift work can lead to nurse fatigue owing to insufficient sleep and inadequate recovery time between shifts. Nurse fatigue has adverse effects on alertness and can affect provision of quality care.

Methods: An observational study using wrist actigraphs was conducted from 2019 to 2020. Participants were 82 rotating-shift nurses who provided direct nursing care in acute hospitals in South Korea. They wore actigraphs for 14 days to measure sleep parameters and predict hourly alertness and reported subjective fatigue before and after every shift.

Results: Nurses demonstrated shorter sleep hours, lower sleep efficiency and longer sleep latency before night shifts compared with other shifts. Fatigue was the highest before day shifts. Sleep parameters and fatigue significantly affected the steep decline in alertness in participants with alertness scores below 70.

Conclusions: Sleep parameters and fatigue level contributed to the differences in decline in alertness across shifts.

Implication for Nursing Management: Findings inform nurse managers, administrators to develop interventions to reduce fatigue, improve sleep quantity and quality and increase alertness among rotating-shift nurses. Management, institutional and individual factors should be considered when developing interventions.

KEYWORDS
actigraphy, fatigue, nurse, shift-work schedule, sleep

1 | BACKGROUND

Nurses are involved in shift work to provide 24-h health care services for patients (Pélissier et al., 2020). South Korean hospitals require most nurses to work 8-h rapid rotating shift work, including night shifts (Hospital Nurses Association, 2019). Adequate recovery sleep between shifts and prior to a shift is a crucial factor affecting nurse performance and high-quality care provision (Ganesan et al., 2019). However, rotating shift work disrupts nurses' circadian rhythm, limits recovery sleep hours, increases fatigue and hinders alertness (Ganesan et al., 2019; Santhi et al., 2007). The reduced cognitive functioning, owing to declined alertness, increases risks for work injuries, work-related errors such as medication administration and procedural and documentation errors, and automobile accidents while commuting (Dorrian et al., 2008; James et al., 2020).

Nurses reported that they experienced sleep disruption on more than 50% of workdays and struggled to remain awake on 27% of such days (Dorrian et al., 2011). Shift work considerably affects nurses' sleep patterns and causes sleep problems, including sleep disturbances, sleep deprivation and poor sleep quality (McDowall et al., 2017; Sun et al., 2019). Such problems have harmful effects on cognitive function, attention, learning and working memory (Dai et al., 2012). The Centers for Disease Control and Prevention (2012) found that over 52% of shift workers in health care sectors sleep less than 6 h/day, which is less than the recommendation of the American Academy of Sleep Medicine and Sleep Research Society (Watson et al., 2015). In a study of 888 UK nurses, 78% of shift-work nurses reported poor sleep quality relative to 59% of non-shift-work nurses (McDowall et al., 2017). Moreover, nurses on night shifts report reduced sleep length and poorer sleep quality than nurses on day and evening shifts (Garde et al., 2009). Short sleep duration was positively associated with impaired everyday memory in shift nurses (Thun et al., 2020) and increased the risk of excessive sleepiness (Chaiard et al., 2018).

Nurses working in an 8-h shift system have higher sleep disturbances levels with more unbalanced sleep duration than those in a 12-h shift system (Costa et al., 2014). Although a few studies assessed the association between sleep parameters and the decline in alertness in nurses working 12-h shifts (Geiger-Brown et al., 2012; Smith-Coggins et al., 2006), studies on rotating-shift nurses in an 8-h shift system are scarce. In Korea, approximately 70% of nurses work 8-h rotating shifts (Park et al., 2014), which consist of day (e.g., 7 AM to 3 PM), evening (e.g., 3 PM to 11 PM), and night shifts (e.g., 11 PM to 7 AM). Korean nurses have different shift schedules each month and work more than 5 days a week (Min et al., 2019) with an average of 47 h a week (Lee et al., 2016). There is no specific pattern for organization of shifts. However, shift nurses typically work in two to four shifts (up to five shifts) in a row, and the shifts change from day shifts to evening shifts and to night shifts every 2–3 days (Min, Kang, & Hong, 2021). Additionally, approximately 92% of rotating-shift nurses had night shifts (Hospital Nurses Association, 2020) and typically worked six or more night shifts per month (two or three consecutive night shifts; Hospital Nurses Association, 2019). On average, nurses have a 15-min break including mealtime. However, in Korea, most shift nurses (96%) could not take regular breaks (Min et al., 2020), wheras nurses in other countries guaranteed their breaks. Considering the working conditions in Korea, Korean nurses are particularly vulnerable to long work hours and insufficient rest, both during and between shifts. Korean shift nurses sleep 6.5 h/day of which 32% experience sleep disturbance (Hospital Nurses Association, 2020). Sleep parameters of shift nurses vary per their shift length (e.g., 8 or 12°h) and type (e.g., day-, evening-, or night-shift). More research on nurses in an 8-h rapid rotating shift is required (Baek et al., 2020).

Nurse fatigue refers to a work-related condition involving exhaustion, tiredness, sleepiness and decreased energy that may result in impaired physical and cognitive functioning (Smith-Miller et al., 2014). Shift work could contribute to nurse fatigue (Royal College of Nursing, 2015). Nurse fatigue leads to work performance deficits such as impaired alertness, long reaction times, concentration difficulties, lack of attention to detail and increased risk of errors (Geiger-Brown et al., 2012; Johnson et al., 2010; Sagherian et al., 2017). It may affect nurses' ability to provide quality care and ensure patient safety (Pélissier et al., 2020; Royal College of Nursing, 2015). Fatigue, sleepiness and decreased alertness are more likely to be present when employees work rotating shifts owing to failed adaptation to circadian rhythm (Dall'Ora et al., 2016). Nurses working rotating shifts also have higher acute fatigue levels relative to those on fixed shifts (Han et al., 2014). Although prior studies have demonstrated that rotating shift work, including night shifts, are associated with increased risk of nurse fatigue, sleepiness and decreased alertness of nurses (Dall'Ora et al., 2016; Øyane et al., 2013), no studies have determined the association between nurse fatigue and the patterns of the decline in alertness during shifts.

Several studies have revealed that sleep deprivation and nurse fatigue have adverse effects on alertness and nurse performance (Caruso et al., 2017). Recognizing this critical issue, the American Nurses Association (2014) highlighted the importance of assessing and examining the risk of sleep problems and nurse fatigue associated with shift work. However, how sleep-related factors and nurse fatigue affect declined alertness requires elucidation. Therefore, we examined the effects of sleep parameters and nurse fatigue on the decline in the alertness of rotating-shift nurses across different shift types using objective measures.

2 | METHODS

2.1 | Study design, setting and sample

We employed an observational study design using data from a project (Scheduling to Avoid Fatigue and Exhaustion) examining changes of alertness among rotating-shift nurses working in acute care hospitals in South Korea. Participants were recruited using a popular schedule management mobile application—'MYDUTY'—and we asked the participating nurses to refer to other colleagues who did not use the mobile application. Inclusion criteria were being a registered nurse who provides direct nursing care for patients and working rotating shifts (includes all three types) in an acute care hospital during the study periods. Exclusion criteria were nurses working in an outpatient department, newly graduate nurses under training and unable to follow actigraphy protocol for 14 days of continuous monitoring. Eighty-four rotating-shift nurses participated, and the valid data from 82 nurses were analysed (two nurses experienced discomfort from wearing the actigraph).

2.2 | Data collection

Data were collected using the ReadiBand wrist actigraphs (Fatigue Science, Vancouver) from June 2019 to February 2020. The

ReadiBand collects data every minute for sleep–wake intervals by tracking the wrist movement using an accelerometer. Participants wore the ReadiBands on their non-dominant hand for 14 consecutive days (including while sleeping, working and in shower) and completed a sleep diary via a mobile link. Participants reported their subjective fatigue level directly before and after every shift via a mobile link that captured the data with the entry time. The research team monitored the collected data every day and encouraged participants using mobile chats to complete sleep diaries and report their fatigue levels to avoid missing data. All participants provided demographic information and their shift-work schedules before and after the study through the online survey link.

2.3 | Measures

2.3.1 | Alertness

Alertness scores were predicted every hour using participants' sleep and wake data captured by ReadiBand based on the biomathematical model of sleep, activity, fatigue, and task effectiveness (SAFTE™) algorithm (Dean et al., 2007). The SAFTE™ algorithm has been validated against laboratory-controlled assessments and is 93% accurate in measuring sleep parameters compared with the gold standard of polysomnography (McCormick et al., 2012; Russell et al., 2000). The measure has been validated in a variety of settings including health care providers (e.g., shift nurses and surgeons; James et al., 2020; McCormick et al., 2012). The ReadiBand has excellent interdevice reliability (Driller et al., 2016). Predicted alertness scores ranged from 0 to 100, and higher scores indicate higher alertness. Scores > 90 indicate 'very low risk', scores 81–90 indicate 'low risk', scores 71–80 indicate 'elevated risk', scores 61–70 indicate 'high risk' (equivalent to 0.08% blood alcohol concentration [BAC] and a reaction time slowed by 55%), and scores < 60 indicate 'very high risk' (equivalent to 0.11% BAC and reaction time slowed by 100%).

2.3.2 | Sleep parameters

Sleep parameters were measured using the ReadiBand wrist actigraphs; they included sleep quantity, sleep efficacy, sleep latency and wake after sleep onset (WASO). Sleep quantity is the total time spent asleep, measured in minutes. Sleep efficacy is the total time in bed divided by total sleep time, expressed as a percentage; a higher percentage indicates better sleep efficacy. Sleep latency is the sleep onset time, measured in minutes. WASO was measured in minutes.

2.3.3 | Fatigue

Participants reported their subjective fatigue level at the beginning of each shift via a mobile survey link. A 10-point scale was utilized, where higher scores represented greater fatigue (Baek & Choi-Kwon, 2017).

2.3.4 | Participants' characteristics

Participants' characteristics were included as covariates. Nurse characteristics included age, sex, marital status, education level, work experience (years), working unit (medical and surgical unit, intensive care unit, operating room and emergency room), nursing care model (functional methods, team nursing, total patient care and mixed type), working hours per week and the number of night shifts during the previous month. Hospital characteristics included location (capital city, another metropolitan area and province), hospital type (tertiary or general), number of beds and teaching-hospital status (yes or no).

2.4 | Data analysis

We analysed data using R version 4.0.3 (R Core Team, 2020). Descriptive statistics (means, standard deviations, frequencies and percentages) were used to describe characteristics and study variables. Differences in measures of fatigue and sleep parameters among shift types were evaluated via the linear mixed model, as was the relationship between these variables and alertness. All linear models incorporated participants' characteristics as covariates. Interaction terms were included in the linear mixed models as independent variables to test the difference in alertness trends per sleep parameters and fatigue levels. Significance was set at $p < .05$.

2.5 | Ethical considerations

The institutional review board of the first author's university approved the Scheduling to Avoid Fatigue and Exhaustion project before data collection began (no. 1041078-201904-HRSB-127-01) and the current study received an exemption for secondary data analysis (no. 1041078-202104-HRSB-108-01). All participants provided written informed consent before participation. Participants were informed about the study aim and methods before participating. They were also informed that participation was voluntary; they had the right to withdraw from the study at any time without penalty. All collected data via a mobile link were stored securely in an online data storage system to ensure confidentiality.

3 | RESULTS

Table 1 presents participants' characteristics. Total 82 nurses participated in this study. The average age of nurses was 26.79 ± 3.05 years, and most of them were female (97.56%) and unmarried (92.68%). The average work experience of nurses was 3.71 ± 2.74 years. More than half of the participants worked in

TABLE 1 Descriptive statistics of participants' characteristics ($N = 82$)

Characteristic	Category	*M* (*SD*) or *n* (%)
Age		26.79 (3.05)
Sex	Female	80 (97.56)
	Male	2 (2.44)
Marital status	Unmarried	76 (92.68)
	Married	6 (7.32)
Education level	Associate degree	3 (3.66)
	Bachelor's degree	76 (92.69)
	Master's degree or higher	3 (3.66)
Work experience (years)	≤1	15 (18.29)
	>1, ≤5	41 (50.00)
	>5, ≤10	25 (30.49)
	>10	1 (1.22)
Working unit	Medical/surgical	52 (63.41)
	Intensive care	22 (26.83)
	Emergency room	6 (7.32)
	Operating room	2 (2.44)
Care model	Functional method	4 (4.88)
	Team nursing	29 (35.37)
	Total patient care	35 (42.68)
	Mixed type	14 (17.07)
Hospital location	Seoul (capital)	55 (67.07)
	Other metropolitan areas	22 (26.83)
	Province	5 (6.10)
Hospital type	Tertiary	78 (95.12)
	General	4 (4.88)
Number of beds	>1,000	35 (42.68)
	>500, ≤1,000	47 (57.32)
Teaching hospital	Yes	62 (75.61)
	No	20 (24.39)
Working hours per week (hours)		47.80 (5.69)
Number of night shifts per month	≤5	18 (21.95)
	>5, ≤10	63 (76.83)
	>10	1 (1.22)

Abbreviations: *M*, mean; *SD*, standard deviation.

medical and surgical units (63.41%) followed by intensive care units (26.83%), emergency room (7.32%) and operating room (2.44%).

Participants had different patterns of shifts during the 14 days of study period, but all patterns included three types of shifts. The average number of working days for each shift were as follows: 2.9 days of day shifts (range 1–9 days), 3.1 days of evening shifts (range 1–8 days), 3 days of night shifts (range 1–7 days; two to three consecutive night shifts) and 5 days off (range 3–7 days). Most of the participants (95.1%) did not have a regular break, and the average break including mealtime was 16.28 ± 12.29 min on their last shift.

Nurses had significantly different sleep quantity ($F = 393.10$, $p < .001$), sleep efficiency ($F = 16.30$, $p < .001$), sleep latency ($F = 127.85$, $p < .001$), WASO ($F = 97.46$, $p < .001$) and fatigue ($F = 241.02$, $p < .001$) between shift types (Table 2). Nurses showed significantly shorter sleep quantity ($t = -21.291$, $p < .001$), lower sleep efficiency ($t = -5.648$, $p < .001$) and shorter sleep latency ($t = -15.018$, $p < .001$) before night shifts than day shifts. Nurses showed significantly shorter sleep quantity ($t = 26.017$, $p < .001$), lower sleep efficiency ($t = 3.352$, $p = .001$) and shorter sleep latency ($t = 11.809$, $p < .001$) before night shifts than evening shifts. Nurses showed significantly longer WASO before evening shifts than day ($t = 8.818$, $p < .001$) and night ($t = 13.769$, $p < .001$) shifts. Moreover, nurses reported highest fatigue levels before day shift than evening ($t = -20.526$, $p < .001$) and night ($t = -17.704$, $p < .001$) shifts.

3.1 | Effects of sleep parameters and fatigue on the decline in alertness

The effect of sleep parameters on the decline in alertness scores was investigated via the mixed-effect linear model with each participant as random intercepts (Table 3). Overall, sleep quantity had a significant relationship with alertness scores ($\beta = 0.136$, $p < .001$). Fatigue was a significant factor affecting the declining alertness scores of day shifts ($\beta = -0.081$, $p = .002$), while sleep quantity ($\beta = 0.486$, $p < .001$) and WASO ($\beta = -0.011$, $p = .015$) were significant factors affecting alertness in night shifts.

Overall, alertness scores in nurses with scores < 70 had significantly different trends for sleep efficiency ($\beta = 0.046$, $p = .009$), sleep latency ($\beta = -0.021$, $p = .037$) and fatigue than those with alertness scores ≥ 70 (Table 4 and Figure 1) ($\beta = 0.049$, $p < .001$). Sleep efficiency ($\beta = 0.089$, $p = .002$) and WASO ($\beta = -0.008$, $p = .037$) were significant factors regarding alertness scores during day shifts, where nurses with alertness scores < 70 differed from scores that were ≥70. Sleep quantity ($\beta = 3.849$, $p < .001$), sleep efficiency ($\beta = 0.307$, $p < .001$) and WASO ($\beta = -0.099$, $p < .001$) were significant factors that showed steeper changes in alertness scores during evening shifts in nurses with alertness scores < 70. Regarding night shifts, sleep quantity ($\beta = -0.308$, $p = .010$), sleep latency ($\beta = -0.024$, $p = .025$) and WASO ($\beta = -0.014$, $p = .012$) had a significantly different effect on changes in alertness scores in nurses with alertness scores < 70.

4 | DISCUSSION

The purpose of our study was to examine the effects of sleep parameters and fatigue on the decline in the alertness of rotating-shift nurses across different shift types using objective measures. According to National Sleep Foundation Guidelines, adults require at least 7 h of

TABLE 2 Descriptive statistics of sleep parameters and nurse fatigue at the beginning of each shift across shift types

Variable	Mean ± *SD*	*F* (*p*)	Comparison	*t* (*p*)
Sleep quantity (hours)				
Overall	6.572 ± 0.897			
Day shift	6.837 ± 1.473	393.10 (<.001)	Evening–day	3.786 (<.001)
Evening shift	6.882 ± 1.324		Night–day	−21.291 (<.001)
Night shift	5.314 ± 1.585		Evening–night	26.017 (<.001)
Sleep efficiency				
Overall	80.296 ± 6.072			
Day shift	81.743 ± 7.150	16.30 (<.001)	Evening–day	−2.359 (.018)
Evening shift	80.599 ± 7.711		Night–day	−5.648 (<.001)
Night shift	79.601 ± 8.512		Evening–night	3.352 (.001)
Sleep latency				
Overall	28.627 ± 11.918			
Day shift	29.955 ± 20.568	127.85 (<.001)	Evening–day	−3.527 (<.001)
Evening shift	25.620 ± 14.711		Night–day	−15.018 (<.001)
Night shift	20.044 ± 13.840		Evening–night	11.809 (<.001)
WASO				
Overall	46.641 ± 29.729			
Day shift	38.062 ± 33.711	97.46 (<.001)	Evening–day	8.818 (<.001)
Evening shift	48.405 ± 35.855		Night - day	−4.310 (<.001)
Night shift	32.195 ± 26.251		Evening–night	13.769 (<.001)
Fatigue				
Overall	5.776 ± 1.626			
Day shift	6.630 ± 1.769	241.02 (<.001)	Evening–day	−20.526 (<.001)
Evening shift	5.387 ± 1.996		Night–day	−17.704 (<.001)
Night shift	5.617 ± 1.763		Evening–night	−3.391 (<.001)

Note. A linear mixed model and the corresponding analysis of variance were used to compare the means of three types of shifts (day-, evening- and night-shift).
Abbreviations: *SD*, standard deviation; WASO, wake after sleep onset.

sleep each night (Hirshkowitz et al., 2015). In our study, participants slept less than the recommended amount on average (6.6 h), especially night-shift nurses (5.3 h). This finding differs from previous ones. James et al. (2020) and Wilson et al. (2019) reported that nurses working fixed 12-h shifts slept for about 7.1 h, and there was no difference between day- and night-shift nurses. Nurses working 12-h shifts can compensate for lost sleep during the night by extra sleep on days off (Riedy et al., 2017). Prior research also reported that nurses working 12-h shifts had less total sleep hours and less sleep efficiency relative to 8-h shift nurses (Rhéaume & Mullen, 2018). Contrarily, our participants showed less sleep efficiency and higher sleep latency in addition to less total sleep hours. Sleep efficiency was 80.30% in this study, below the healthy rate (85%; Reed & Sacco, 2016). Compared with previous studies that reported fairly normal time to fall asleep (sleep latency) regarding among hour fixed shift nurses (James et al., 2020), our participants reported more time to fall asleep (28.63 min). We also found a significant difference between shifts, where nurses working night shifts spent less time sleeping and more time to fall asleep, which differs from James et al.'s (2020) findings concerning 12-h fixed shift nurses. This could be explained by the working environment of nurses in Korea. Most Korean nurses work 8-h rapid rotating shifts, with no pattern for how shifts are arranged, for an average of 47 h a week (i.e., working 5 days a week; Lee et al., 2016; Min et al., 2019) relative to about 39 h/week in the United States (U.S. Department of Health & Human Services, 2010). Min et al. (2020) reported that many nurses worked 6–10 night shifts per month despite not being fixed as night-shift nurses. Thus, South Korean nurses who work rapid rotating shifts must more often adjust their circadian rhythm, resulting in a longer time to fall asleep, which hinders sleep quantity.

Fatigue level was highest in nurses' working day shifts relative to their counterparts, and the fatigue level at the beginning of the day shift significantly affects alertness. Thus, it is crucial to decrease fatigue levels at the beginning of shifts among day shift nurses to avoid the risks of human error. To decrease the fatigue levels and keep nurses alert while on duty, shift scheduling that allows for adequate intershift recovery is important (Min et al., 2019). Therefore, the direction for rotating the shift (e.g., clockwise

TABLE 3 The effect of sleep parameters and self-reported fatigue at the beginning of each shift and on changes in alertness scores

	Estimate	*SE*	*Df*	*t*	*p*
Overall					
Sleep quantity	0.136	0.046	3153.057	2.950	.003
Sleep efficiency	−0.002	0.012	2823.542	−0.158	.874
Sleep latency	−0.002	0.004	3147.181	−0.470	.638
WASO	−0.002	0.003	2653.693	−0.885	.376
Fatigue	−0.043	0.044	537.486	−0.978	.328
Day shift					
Sleep quantity	−0.002	0.028	1388.278	−0.070	.945
Sleep efficiency	−0.009	0.011	1265.706	−0.773	.440
Sleep latency	−0.004	0.002	1339.800	−1.753	.080
WASO	−0.003	0.002	1164.926	−1.311	.190
Fatigue	−0.081	0.026	1136.366	−3.066	.002
Evening shift					
Sleep quantity	0.043	0.057	464.604	0.756	.450
Sleep efficiency	−0.015	0.016	549.335	−0.956	.340
Sleep latency	−0.004	0.004	604.707	−1.236	.217
WASO	−0.001	0.003	504.716	−0.356	.722
Fatigue	−0.008	0.039	168.620	−0.209	.835
Night shift					
Sleep quantity	0.486	0.076	1335.713	6.430	<.001
Sleep efficiency	−0.014	0.015	1315.169	−0.896	.370
Sleep latency	−0.003	0.009	1296.948	−0.328	.743
WASO	−0.011	0.004	1497.363	−2.437	.015
Fatigue	−0.119	0.091	834.586	−1.304	.192

Note. Hospital, unit and employee factors were included in the estimation as covariates. Hospital factors were location, hospital type, number of beds and teaching status. Unit factors were working unit type and care model. Nurse factors were age, sex, marital status, education level, work experience, working hours during the previous week and the number of night shifts. The models also adjust for the baseline alertness.
Abbreviations: *df*, degree of freedom; *SE*, standard error; WASO, wake after sleep onset.

TABLE 4 The effect of sleep parameters and self-reported fatigue at the beginning of each shift on patterns of the decline in alertness scores comparing the nurses with alertness scores lower than 70 during shifts and those who with alertness scores equal to or larger than 70

	Estimate	*SE*	*Df*	*t*	*p*
Overall					
Sleep quantity × alertness < 70	0.175	0.101	4599.188	1.740	.082
Sleep efficiency × alertness < 70	0.046	0.017	4703.635	2.625	.009
Sleep latency × alertness < 70	−0.021	0.010	4314.693	−2.088	.037
WASO × alertness < 70	0.006	0.004	4712.327	1.278	.201
Fatigue × alertness < 70	0.493	0.099	4491.093	4.967	<.001
Day shift					
Sleep quantity × alertness < 70	0.025	0.060	1496.931	0.418	.676
Sleep efficiency × alertness < 70	0.089	0.028	1300.413	3.124	.002
Sleep latency × alertness < 70	−0.003	0.023	1497.047	−0.127	.899
WASO × alertness < 70	−0.008	0.004	1052.104	−2.093	.037

(Continues)

TABLE 4 (Continued)

	Estimate	*SE*	*Df*	*t*	*p*
Fatigue × alertness < 70	0.273	0.149	897.847	1.836	.067
Evening shift					
Sleep quantity × alertness < 70	3.849	0.787	1597.147	4.888	<.001
Sleep efficiency × alertness < 70	0.307	0.078	1598.260	3.925	<.001
Sleep latency × alertness < 70	0.214	0.150	1601.350	1.424	.155
WASO × alertness < 70	−0.099	0.021	1600.369	−4.734	<.001
Fatigue × alertness < 70	−0.645	0.466	1601.948	−1.384	.166
Night shift					
Sleep quantity × alertness < 70	−0.308	0.120	1553.494	−2.566	.010
Sleep efficiency × alertness < 70	0.027	0.018	1568.399	1.544	.123
Sleep latency × alertness < 70	−0.024	0.011	1553.529	−2.250	.025
WASO × alertness < 70	−0.014	0.005	1560.143	−2.515	.012
Fatigue × alertness < 70	0.072	0.112	1565.908	0.642	.521

Note. Hospital, unit and employee factors were included in the estimation as covariates. Hospital factors were location, hospital type, number of beds and teaching status. Unit factors were working unit type and care model. Nurse factors were age, sex, marital status, education level, work experience, working hours during the previous week and the number of night shifts. The models also adjust for the baseline alertness.
Abbreviations: *df*, degree of freedom; *SE*, standard error; WASO, wake after sleep onset.

vs. counterclockwise) and the number of consecutive work shifts should be considered when scheduling rotating-shift nurses. In Korea, by Labor Standards Act (2018), nurses are guaranteed a rest period of 11 consecutive hours between shifts. However, mandatory overtime could interrupt the time off between shifts (Min et al., 2019) as nurses work 1.3 h of overtime/day on average (Lee et al., 2016). Policy development guaranteeing an adequate rest period and reducing mandatory overtime is crucial in Korea.

Notably, sleep parameters (sleep quantity, efficiency, latency and WASO) were significant factors affecting the steep drop in alertness in participants with scores below 70. These sleep parameters were unsatisfactory, especially in nurses working night shifts relative to their counterparts. Ganesan et al. (2019) reported that the sleep–wake cycle between different shift types is altered in rotating-shift health care workers, and alertness and performance were most impaired during night shifts because of the lack of circadian adaptation. Rotating-shift nurses have also reported more challenges in initiating sleep than fixed night-shift nurses (Oh et al., 2017). The Korean Ministry of Health and Welfare (2019) encouraged the health care system to incorporate policies regarding the implementation of fixed night shifts to reduce the burden on rotating-shift nurses. However, more studies using objective measures, such as actigraphy, are needed to compare the effectiveness of sleep patterns between fixed night shifts and rotating-shift nurses.

Previous research related to sleep, fatigue and shift work among nurses mostly relied on self-reported sleep measures (Barker & Nussbaum, 2011; Griffiths et al., 2014). They can be easily collected but are prone to recall-bias and may not provide accurate information. Thus, one novel aspect of this study is using an objective measure (the ReadiBand wrist actigraphy) to collect data on sleep–wake intervals and calculate alertness scores and sleep parameters. Although the gold standard for objective sleep assessment is using polysomnography, it requires participants to visit sleep centres or to use portable equipment that is inconvenient and increases costs (Natale et al., 2014). Compared with polysomnography, actigraphy using wrist-worn Readiband is thus convenient and can also measure sleep parameters accurately (McCormick et al., 2012; Russell et al., 2000). Moreover, a special feature of Readiband (SAFTE™ algorithm) objectively predicts alertness scores based on sleep and wake patterns that are particularly relevant for shift nurses (Hursh & Eddy, 2005; James et al., 2020). Future studies using objective measures to accurately capture the sleep patterns and alertness in rotating-shift nurses are highly recommended.

4.1 | Limitations

Fatigue is multidimensional and may include acute and chronic fatigue and intershift recovery (Winwood et al., 2005). We measured the fatigue level variability by assessing the level before and after the shift without considering multidimensionality. Future studies must incorporate factors that may impact sleep patterns, such as physical and psychological illness and family responsibilities. We did not control for nurses' health status (e.g., menstrual period and past medical history), which may affect alertness and nurse performance (Vidafar et al., 2018). Although we tried to include nurses from various age groups, our participants were relatively young, perhaps because they were recruited through an online scheduling programme and older age groups may not prefer using it. Future studies may need to recruit participants using both online and offline procedures.

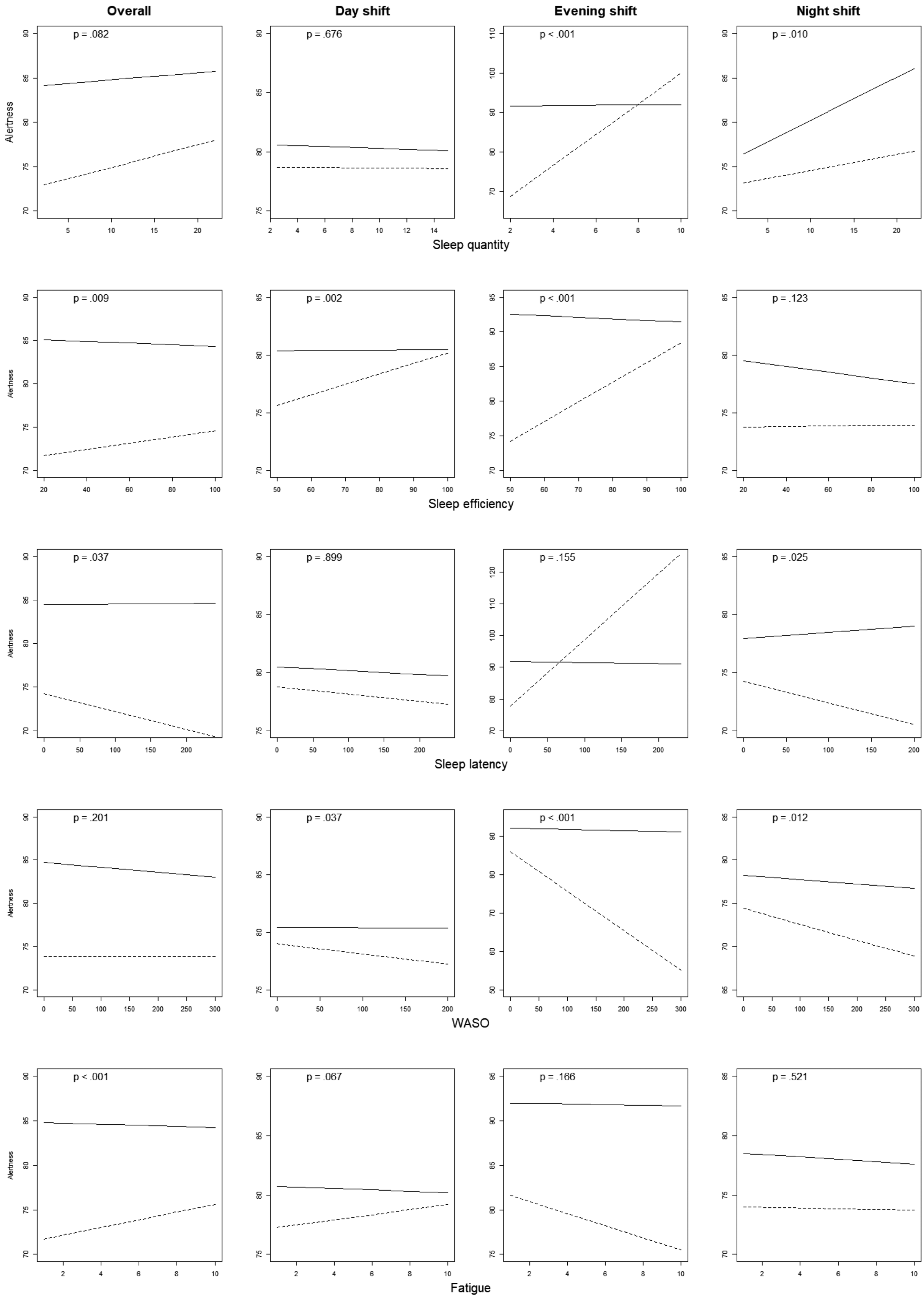

FIGURE 1 Interaction of sleep parameters and self-reported fatigue with different levels of alertness. The solid lines represent the estimated slopes when the alertness is larger than or equal to 70; the dotted lines demonstrate the alertness trend (<70). WASO, wake after sleep onset

5 | CONCLUSION

This observational study revealed that sleep patterns and fatigue levels differed across nursing shifts. Sleep parameters and fatigue contributed to declined alertness across shifts. Interventions that incorporate the different features of each shift must be developed to improve sleep quantity and quality, decrease fatigue, prevent medical errors and improve patient safety.

5.1 | Implication for nursing management

Management, institutional and individual factors should be considered when developing interventions. The characteristics of the shift system, such as length, the speed of rotation, the number of consecutive shifts and the recovery period between consecutive shifts are essential to improve nurses' sleep quantity and quality (Sun et al., 2019). Managers and administrators must be educated on health and safety risks associated with rotating shift schedules. At the individual level, healthy dietary and lifestyle practices (e.g., limiting caffeinated drinks, promoting physical exercise and melatonin administration) may effectively promote sleep (Fang & Li, 2015; McCulloch & Ferguson, 2010).

Intershift recovery by providing sufficient sleep and rest period is important for rotating-shift nurses. Overtime leads to longer working hours, thus shortening the intershift recovery period (Min, Kim, et al., 2021). The current Labor Standards Act (2018) in Korea does not fully incorporate specific environmental factors of health care settings, and both voluntary overtime and involuntary overtime limit adequate sleep and rest in nurses (Bae et al., 2018). Hence, mandatory regulation and policy development limiting overtime and securing adequate intershift recovery period among rotating-shift nurses are urgent in Korea. Furthermore, managers and administrators should monitor nurses' overtime hours and understand that inadequate staffing level and increased acuity of patients could increase workloads which many be important contributors to increased overtime. Lastly, future research is recommended to identify the effects of specific characteristics of overtime (e.g., overtime hours and consecutive overtime days) on the decline in the alertness of rotating-shift nurses to guide nurse managers, administrators and policymakers to develop and implement effective strategies and policy.

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CONFLICT OF INTEREST

The authors declare no actual or potential conflicts of interests.

AUTHOR CONTRIBUTIONS

AM and HH designed the study and collected the data. AM, SS and TL analysed the data. AM supervised the study. AM, HH, SS and TL wrote the manuscript. AM and HH was responsible for the critical revisions for important intellectual content.

ETHICAL APPROVAL

The study received an exemption from the Institutional Review Board of a University (Approval No. 1041078-202104-HRSB-108-01).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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