Title: An Association Between Sleep and Fatigue in Nurses Engaged in 16-hour Night Shifts in Japan: Assessment Using Actigraphy

Running Title: SLEEP AND FATIGUE OF SHIFTWORK NURSES

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Abstract

Aim: To determine the association between sleep and fatigue in nurses working in a two-shift system including 16-hour night shifts.

Methods: Sixty-one nurses were assessed on their sleeping and napping over nine days, using actigraphy and a sleep diary. Work-related feelings of fatigue were measured using the "Jikaku-sho shirabe" questionnaire and the Cumulative Fatigue Symptoms Index.

Results: The main nighttime sleep started after 00:00 in half of the participants, and the average start and end times were significantly delayed among participants in their 20s compared to those in their 40s (01:00 to 08:48 vs. 23:58 to 07:25, respectively) in the study period. Although about 90% of participants napped during and/or after a night shift, only 50.8% napped for over 2 h during their shift and 32.8% napped in the morning after a night shift. In a high-fatigue group, significantly more nurses went to sleep after 00:25 than before 00:26 the night after a night shift. Further, nurses who napped for over 2 h during their night shift exhibited a significantly lower rate of some cumulative fatigue symptoms compared to those who did not. In addition, a combination of napping in the morning after a night shift and beginning the following nighttime sleep before 00:26 was associated with a significant decrease in fatigue

symptoms.

Conclusions: Naps at an appropriate time and of an appropriate duration, along with the practice of beginning the nighttime sleep early after a night shift, may relieve cumulative mental fatigue in nurses working 16-hour night shifts.

Key words: actigraphy, fatigue, shift-work, sleep, nurses

Introduction

Shift work is necessary for nurses to provide 24-hour on-site patient care. Night-shift workers are prone to sleep deprivation, misalignment of circadian rhythms, and subsequent sleepiness and sleep-related performance deficits. In Europe and the United States, a pattern of two 12- to 13-hour shifts per day is becoming common in many hospitals to reduce shift-to-shift handovers, staffing overlap, and costs, and to satisfy nurses' need for work-life balance. However, it has been noted that there are risks associated with 12-hour shifts: medical errors (Griffiths et al., 2014; Rogers et al., 2004; Scott, Rogers, Hwang, & Zhang, 2007), fatigue and performance degradation (Geiger-Brown et al., 2012; Wilson et al., 2017), reduced sleep time and sleep efficiency (Rhéaume & Mullen, 2018), an increase in the risk of drowsy driving accidents (Lee et al., 2016; Scott, Hwang, et al., 2007), and a risk of burnout and job dissatisfaction (Dall'Ora, Griffiths, Ball, Simon, & Aiken, 2015; Stimpfel, Sloane, & Aiken, 2012).

In Japan, since around 2000, the two-shift system has been gradually replacing the traditional three-shift system. 55.1% of wards using the two-shift system have their nurses work a long night shift of more than 16 hours (Japan Federation of Medical Worker's Unions, 2016). This working pattern, with a 16-hour night shift, is becoming more common, as a result of its several advantages: nurses need to work fewer night shifts,

meaning that their circadian rhythm tends not to be as disrupted (Takahashi et al., 1999); their lifestyle is more balanced (Ichikawa, 1998); the two-shift system is preferred by young nurses (Hara, 2009); and a nap during each night shift is guaranteed. On the other hand, nurse fatigue and drowsiness are increased by long night shifts (Matsumoto et al., 2008), and changing to 16-hour night shifts did not improve the contents of daily activities (Matsumoto, 2015). Given these working conditions, the Japan Nursing Association published a set of "Guidelines on Night Shift and Shift Work for Nurses" (Japanese Nursing Association, 2013; hereafter referred to as the "Guidelines"). The Guidelines published by the Japan Nursing Association recommend that nurses adhere to the following pattern of napping: take a nap for around two hours before beginning a night shift; take a nap for more than two hours during the night shift; and go to sleep at home as early as possible the night after a night shift, but take a nap during the day for around two hours to avoid disturbing the pattern of nocturnal sleep.

Napping is effective in reducing drowsiness and in preventing attention and performance deterioration (Geiger-Brown et al., 2016; Lovato, Lack, Ferguson, & Tremaine, 2009; Smith, Kilby, Jorgensen, & Douglas, 2007). Furthermore, taking a nap before and after night shifts reduced nurses' fatigue (Kayahara & Taniguchi, 2014). Fatigue was lower after night-shift work in nurses who woke up at the same time as on

regular days in the morning than those who woke up later on the night-shift work morning (Miyazaki & Hosona, 2013).

These facts suggest that fatigue among shift-working nurses is related to their napping habits and wake-up time. However, most of the above-mentioned studies used questionnaires; there are few studies that objectively evaluate nurses' sleep. Furthermore, following publication of the Guidelines, there has been no report verifying whether nurses follow the napping pattern suggested or investigating the fatigue-mitigating effects of napping.

Therefore, in this study, we evaluated sleep data collected using actigraphy from nurses working 16-hour night shifts and clarified the relationship between sleep and fatigue. These findings could serve as fundamental data regarding nurses' fatigue levels. We hypothesized that fatigue would be higher when nurses do not take a nap according to the guidelines and the starting time of the main sleep are late.

Study aim

To determine an association between sleep including napping and fatigue measured using actigraph in nurses working on a two-shift system with 16-hour night shift in Japan.

Definition of operational terms

Two-shift system: Day shift from 08:30 to 17:00 hours; Night shift from 16:30 to 09:00 hours on the next day.

Nap: Short sleep taking before, during and after night shifts. About two hours napping is allowed once during night shifts at this facility.

Methods

Study design and participants

This study used a quantitative, descriptive, cross-sectional research design.

Of nurses invited to participate in the study, those who agreed to respond were recruited. The participants consisted of the nurses who engaged in two-shift system including 16-hour night shift in the general ward in Hospital A that had over 200 beds in , northern Japan. Only the nurses who were not on a vacation during the course of the study. The nurses were grouped into three categories of 25 each based on age as follows: 20 to 30 years, 30 to 40 years, and 40 to 50 years. Thus, a total of 75 nurses were included. The nurses who always took sleeping pills or were under treatment for any disease were excluded.

Measures

Sleep

Actigraph

The actigraph (Micro-mini RC; Ambulatory Monitoring, Inc. NY, USA) was used for assessment of the sleep. For analyze of sleep, Cole's formulation with at least 90% of correlation in comparison with the polysomnogram was used.

To avoid artefacts, the subjects were asked to wear the actigraph on the non-dominant wrist for consecutive nine days. After data collection, the actigraph was connected to a personal computer via the interface for exclusive use of the actigraph (Ambulatory Monitoring, Inc. NY, USA). The data were downloaded via the exclusive software (ActMe; Ambulatory Monitoring, Inc. NY, USA). Using a software (AW2; Ambulatory Monitoring, Inc. NY, USA), analyzed their sleep. The data that were recorded when the subjects did not wear the actigraph were excluded from the analysis.

The sleep parameters used for the analysis are the following items: Total Sleep time (TST), Sleep efficiency (SE), Sleep-onset latency (SOL), Wake minute after sleep onset (WASO), start time of main sleep, end time of main sleep, number of long (lasting ≥ 5 min) sleep episodes (LSEP), and duration of longest sleep episode (LGSEP).

(1) Total Sleep time (min): sleep duration; *the time when the first sleep block for

20 minutes or more was initiated in bed for the first time was defined as sleep-onset time.

(2) Sleep efficiency (%): the percentage of all sleep time accounts for the time from initiation of sleep to getting up.

(3) Sleep-onset latency (SOL): the time from onset of resting stage to initiation of sleep (the time when the first sleep episode for 20 minutes or more was initiated).

(4) Wake after sleep-onset (WASO): wake minute during sleep-onset to sleep-offset interval.

(5) Long sleep episodes (LSEP): total number of sleeping blocks for at least five minutes during sleep.

(6) Longest sleep episode (LGSEP): duration of the longest sleep episode in minutes.

Sleep diary

Participants were asked to record their activities, sleep time, daytime sleepiness, number of occasions of alcohol intake, and any medication taken over the period during which they wore the actigraph.

Morningness-Eveningness Questionnaire

The Morningness-Eveningness Questionnaire (MEQ), which was developed by Horne and Östberg (Horne & Ostberg, 1976), was used in translation into Japanese. Based on each participant's MEQ score, their circadian typology was classified as falling into one of five categories: definite morning type, moderate morning type, intermediate type, moderate evening type, or definite evening type. The participants were asked to complete the questionnaire at the beginning of the study.

Fatigue

Cumulative Fatigue Symptoms Index

The Cumulative Fatigue Symptoms Index (CFSI) developed by Kosugo *et al*. (Fujii, Kosugo, & Hirata, 1993; Kosugo, 1991) was used. The CFSI evaluates signs of workers' cumulative fatigue and comprises 81 questions. The subjects answer each question by choosing between two options. The CFSI is composed of eight characteristic groups of items: for physical aspects, "general fatigue," "chronic fatigue sign," and "physical disorders"; for mental aspects, "depressive feelings," anxiety," and "decreased vitality"; for social aspects, "irritability" and "unwillingness to work. The rate of positive items is shown as the complaint rate. According to Kosugo's criteria, the complaint rate was calculated as follows (Fujii et al., 1993): Complaint rate (%) =

[Number of positive items/ (Number of each category items × Number of subjects)] × 100. The subjects were asked to complete the CFSI initially and at one week and one month after the initiation.

Subjective Feelings of Fatigue

Subjective fatigue symptoms were assessed with a questionnaire on work-related fatigue Jikaku-sho Shirabe (Kubo et al., 2008), which was proposed by the Industrial Fatigue Research Committee of Japanese Occupational Health in 2002. This questionnaire comprises 25 items of subjective fatigue that were categorized into five factors: Group I, sleepiness; Group II, unstable feeling; Group III, unpleasantness; Group IV, tiredness; Group V, blurriness. In each question item, the subjects chose one from the following options: “Strongly Disagree (1 point)”; “Disagree (2 points)”; “Slightly Agree (3 points)”; “Agree (4 points)”; “Strongly Agree (5 points).” A higher score indicates more fatigue. The subjects were asked to complete the questionnaire twice a day, i.e., before and after work on duty days and at the wake up time and bed time on days off. We used the total score: before work and wake time as a total score of "before"; after work and bedtime as a total score of "after" to compare their subjective feeling of fatigue as a function of nap and sleep.

Demographics

Participants were asked to provide personal details of their age, gender, body mass index, years of experience as a nurse, years of nursing experience in their current ward, number of dependents at home requiring nursing or care, any disease under treatment, and any medication they were taking.

Statistical analysis

Descriptive statistics were computed for each dependent variable. We used the Kruskal-Wallis test and Tukey's Honestly Significant difference test to identify variation in sleep patterns associated with age. “Jikaku-sho shirabe” subjective fatigue scores were collated for each participant and categorized as “before” scores (collected before starting work and at wake-up on days off) or “after” scores (collected at the end of work and at bedtime on days off). The “before” and “after” scores were highly correlated ($r = 0.7$, $p < .01$); therefore, participants were divided into two groups with a high and low degree of subjective fatigue based on the median “after” score. The student's *t* test was used to compare sleep parameters between the two groups.

We divided the groups by sleep as follows: napping before night shifts, napping

during night shifts, napping after night shifts. Also, we divided the groups by sleep start time at median value (00:25) as follows: at night after night shifts, at night before day shifts. After evaluating the relationship between these groups and fatigue, two variables, the start time of the nighttime sleep after a night shift and the timing of the nap following a night shift, were combined to examine the relationship of overall sleeping pattern after a night shift with fatigue.

The chi-squared test and Fisher's exact test were used to compare the duration and timing of naps taken before, during, and after a night shift between the two groups.

Radar charts representing the mean complaint rate in each category of the CFSI are presented to compare the following groups: nurses who napped for over 2 hours during their night shift vs. those who did not; nurses who napped in the morning after their night shift vs. those who did not; and those following a generally early sleeping pattern vs. those following a generally late sleeping pattern. Actigraphy data were analyzed for 49 participants; the others were excluded as a result of missing data. There were three participants for whom only the first day of their night shift was included in the data collection period, and two for whom only the second day was included; these participants were excluded from analyses comparing variation in fatigue by sleep start time and napping pattern.

SPSS Statistics v. 24 for Windows (IBM Corp., Armonk, NY, USA) was used to carry out all statistical analyses, and the significance threshold was set at 5%.

Ethical considerations

This study was approved by the ethical review board of the authors' affiliated university and of the participated facility. The participants were informed of the purpose, procedures, and potential publication of this study, as well as their rights of refusal and confidentiality. Written informed consent was obtained from the participants.

Results

Participants' characteristics

A total of 61 participants were recruited to take part in this study. After the exclusion of two who withdrew and four who did not work a night shift during the data collection period, the remaining participants were 27 nurses in their 20s (44.3%), 25 in their 30s (40.9%), and nine in their 40s (14.7%). In terms of chronotype, the intermediate type accounted for 73.8% of participants and there were no participants with the definitely morning type and definitely evening type of circadian typology. Nurses who live with family members who need childrearing and care were only six

people in their 30s (Table 1).

Data on participants' sleeping and napping patterns

Sleep

The average total sleep time across all participants was 8.3 ± 1.4 h daily; the subgroup average was 8.6 ± 1.3 h among participants in their 20s and 8.7 ± 2.0 h among those in their 40s. The average main sleep start time across all participants was 00:30 ± 1:03, with half of the participants beginning their nighttime sleep after 00:00. Participants in their 20s recorded significantly later average sleep onset (01:00 ± 0:49) and offset (08:48 ± 1:11) times than those in their 40s (23:58 ± 0:54 and 07:25 ± 0:39, respectively); in general, sleep phases tended to be delayed as participants aged (Table 2). There were no significant differences in sleep duration or timing based on basic attributes, such as years of experience in the department or number of overtime hours.

Napping

Compared to the napping recommendation given in the Guidelines, the overall proportion of participants who napped before a night shift was low, at 39.0%. The rates of napping during and after a night shift were high, at 91.5% and 89.7%, respectively.

However, the proportions of participants who napped for 2 hours or more during their night shift and in the morning after their night shift were low, at 50.8% and 32.8%, respectively. The proportion of participants who napped before their night shift was lower in every age group, but especially among participants in their 20s, of whom 73.1% did not take such a nap. Among participants in their 20s, 20.0% did not take a nap after a night shift (Table 3).

The relationship between sleeping and napping patterns and subjective fatigue in each group

There was no major difference in age between the high and low subjective fatigue groups.

The relationship between main sleep pattern and fatigue

There were no significant differences between the two groups in terms of sleep variables (Table 4). However, in a comparison of sleep start time for the nighttime sleep following a night shift, there were significantly more participants with a sleep onset time after 00:25 than with a sleep onset time before 00:26 in the high fatigue group (Table 4). There were no significant differences between the two groups in terms of the basic

attributes such as age, years of nursing experience, number of night shifts, overtime hours, chronotype, child rearing or care.

The relationship between napping and fatigue

The timing of naps taken before and after the night shift and the duration of naps taken during the night shift were compared between the high- and low-fatigue groups. There was no significant difference between the groups on these items (Table 4).

The relationship between nap and sleep timings and fatigue

Two variables, the start time of the nighttime sleep after a night shift and the timing of the nap following a night shift, were combined to examine the relationship of overall sleeping pattern after a night shift with fatigue.

We defined an early group as consisting of those participants who would take a nap in the morning after a night shift and start their nighttime sleep that night before 00:26, while the late group consisted of participants who would take a nap in the afternoon after a night shift and start their nighttime sleep after 00:25 that night. There was no significant difference between the high and low subjective fatigue groups in terms of membership in the early group vs. the late group (Table 4).

The relationship between sleep and cumulative fatigue

In a comparison of CFSI scores, the average complaint rates for decrease in vitality, unwillingness to work, general fatigue, and signs of chronic fatigue were significantly lower, by 12–19%, among those participants who napped for 2 h or more during their night shift than among other participants (Figure 1). There were no significant differences between the two groups in terms of the basic attributes such as age, years of nursing experience, number of night shifts, overtime hours, chronotype, and child rearing or care.

There was no significant difference between participants who took a nap in the morning following a night shift and other participants (Figure 2). However, in a comparison between the early and late groups as defined above, the average complaint rate was 10–25% lower among the early group than among the late group; specifically, complaint rates were significantly lower among the early group for anxiety, decrease in vitality, unwillingness to work, and signs of chronic fatigue (Figure 3). There were no significant differences between the two groups in terms of the basic attributes such as age, years of nursing experience, number of night shifts, overtime hours, chronotype, and child rearing or care.

Discussion

Sleeping and napping patterns of nurses working 16-hour night shifts

Generally, in shift work, sleep is disturbed by circadian rhythm modulation, and loss of sleep time is reported (Colten & Altevogt., 2006; Flynn-Evans et al., 2018; Geiger-Brown et al., 2012). However, the average sleeping time of participants in this study period was 8.3 ±1.4 h and they had got sufficient sleep unlike 12h shift work nurses (Geiger-Brown et al., 2012; Wilson et al., 2017). Participants in this study showed high cumulative fatigue. Therefore, it is considered that participants eliminate high cumulative fatigue by adopting a long sleeping time.

As mentioned previously, The Guidelines by the Japanese Nursing Association recommend nurses appropriate way of napping.

In the present study, the proportion of participants who napped during their night shift was as high as about 90%, but the duration of this nap was shorter than 2 hours in about 50% of cases. In addition, the rate of napping before a night shift was 39%, and the rate of napping in the morning after a night shift was as low as about 33%. In other words, although nurses generally did nap, it is clear that the proportion of nurses following a napping pattern in accordance with the Guidelines was very low.

Among participants in their 20s, the rate of napping was low: 73% of participants did not take a nap before their night shift, 20% did not take a nap after their night shift, and 42% took a nap lasting less than 2 hours during their night shift. Only 28% of participants in this group took a nap in the morning after their night shift. In other words, the rate of napping was lower among participants in their 20s than among those in other age groups. Furthermore, in all age groups, the proportion of participants taking a nap of 2 or more hours during their night shift and a nap in the morning following a night shift was low.

These findings are in accordance with those of (Asaoka et al., 2013) that 92% of two-shift workers report that they are given the opportunity to nap during their night shifts, but that 43% report that they always or often miss this opportunity as a result of their workload. The low rate of nap-taking described above may be attributed to the fact that it is difficult for nurses to find time to nap, as a result of the highly stressful, demanding, and time-pressured environment (Ruggiero & Redeker, 2014); avoiding nap because of sleep inertia (Fallis, McMillan, & Edwards, 2011; Kubo et al., 2010); additionally, a quiet space appropriate for napping may be unavailable (Purnell, Feyer, & Herbison, 2002).

The relationship between napping and cumulative fatigue during a night shift

Naps are recommended to prevent performance deterioration and reduce sleepiness in healthcare workers (Barthe, Tirilly, Gentil, & Toupin, 2016; Dinges, Orne, Whitehouse, & Orne, 1987; Geiger-Brown et al., 2016; Japanese Nursing Association, 2013; Lovato et al., 2009; Smith-Coggins et al., 2006). Taking a 120-minute nap at 02:00-04:00 decreased fatigue of nurses working 16-h night shift (Oriyama & Miyakoshi, 2017). Kikuchi & Ishii (2015) reported that fatigue is high if nurses cannot take a nap during a night shift.

On the other hand, it has been reported that sleepiness is strong and fatigue is not alleviated even if nap time can be taken for 2 hours because 16 hours night shift is maintained for day-shift oriented biological rhythm (Matsumoto et al., 2008; Sasaki & Matsumoto, 2013).

However, as a result of the present study, it now clear that a nap of more than 2 hours during a night shift significantly reduces aspects of cumulative fatigue, such as a decrease in vitality, unwillingness to work, general fatigue, and signs of chronic fatigue.

These results suggest that shift workers exposed to stressors at night may experience difficulty managing physiological and mental responses to these stressors (James, Honn, Gaddameedhi, & Van Dongen, 2017).

Inappropriate nap-taking is known to be a factor in causing medical accidents, but this study further reveals that appropriate nap-taking is also associated with a decrease in demotivation and chronic fatigue, which in turn may reduce turnover of nurses.

In addition, although there was no significant difference between subjective feelings of fatigue and napping, a significant difference was recognized in CFSI, which means that to evaluate the effect of a nap on fatigue, it may be necessary to focus on chronic fatigue rather than acute fatigue.

The relationship between nap and main sleep start time and fatigue

Taking a nap in the morning following a night shift was not by itself effective in reducing cumulative fatigue. However, the results make it clear that cumulative fatigue is greatly alleviated by combining a morning nap with going to bed early the night after a night shift. This seems to be because there is a possibility that this sleeping pattern may avoid the tendency for sleep phases to shift gradually later.

Misalignment between the circadian pacemaker and the sleep-wake cycle may result in shift work disorder (Barger et al., 2012; Wright, Bogan, & Wyatt, 2013). Hospitalists can help limit fatigue and improve performance and safety through circadian adaptation (Schaefer, Williams, & Zee, 2012). In other words, optimal timing of the nap

taken after a night shift and the worker's bedtime that night not only prevents cumulative fatigue, but may also prevent disruption of the circadian rhythm and lower the risk of shift work disorder.

Regarding the relationship between sleeping patterns and fatigue, Miyazaki and Hosona (2013) report that wake-up time in the morning before a night shift and wake-up time on an ordinary day are associated with fatigue after a night shift. In addition, in the present study, the results showed that sleep onset time and napping pattern are related to fatigue.

The Guidelines suggest taking a nap, but do not mention the effects of not doing so on the nurse's levels of tiredness. In the present study, we observed that it is not sufficient to merely take a nap at some point; napping at an appropriate time and for an appropriate duration is essential for nurses to avoid symptoms of fatigue. In addition, we clarified that the combination of the timing of the nurse's nap following a night shift and their bedtime that night is a significant factor in decreasing their levels of mental and social fatigue, including anxiety, a decrease in vitality, and unwillingness to work. Avoidance of these aspects of fatigue is essential for nurses to keep their motivation for work.

Based on the above findings, our study suggests that cumulative fatigue can be

mitigated by nap-taking and timing the start of the nighttime sleep appropriately. In future research, it will be necessary to carry out similar investigations with a larger number of participants and to replicate the findings.

Limitations of the study

The participants in this study were recruited from a single institution (a general hospital) in a single region. Therefore, there may be a bias (e.g., in the characteristics of the region or the institution) that means that it is difficult to generalize the results to all nurses in Japan who work in a two-shift system including a 16-hour night shift. The nap environment (i.e., availability for a room and a bed for naps, napping position, darkness and noise in the room during naps), lifestyle factors (i.e., coffee consumption, smoking), and nocturnal sleep conditions (i.e., study participant is sleeping in bed with a partner or alone during nocturnal sleep) influences the effects of nap; however, this study did not investigate these factors.

In addition, quality of sleep should be assessed by combining participants' subjective feelings about their sleep with objective measures, while the present study measured only the latter. Furthermore, considering nurses' shift patterns and the need to allow for loss of some data, it would be better to extend the actigraphy data collection

period to two weeks.

Conclusion

The proportion of nurses who take naps before, during, and after their night shifts, in accordance with published Guidelines, was revealed to be low, at 27 to 50%. We found that taking a nap and timing bedtime appropriately after a night shift decreases cumulative fatigue, and that this effect relates not only to physical fatigue but also to mental fatigue, the avoidance of which is related to factors important in the continuation of employment, such as keeping workers motivated. In addition, our results suggested speculation that an appropriate pattern of napping and nighttime sleeping may help to avoid collapse of the circadian rhythm, with sleep phases tending to shift gradually later. Therefore, we suggest that nursing team leaders should ensure that a suitable environment for napping is available and encourage a workplace culture that promotes taking a nap during night shifts and leaving promptly at the end of a shift.

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Conflict of interest

No conflict of interest has been declared by the authors.

Author Contributions

H. K., N. S, Y. Y., N. S., F. N. and R. Y. contributed to the conception and design of this study; H. K., Y. Y. and N. S. contributed acquisition of data; N. S. contributed to the analysis of data; H. K. and R. Y. performed the statistical analysis and drafted the manuscript; R. Y. critically reviewed the manuscript and supervised the whole study process. All authors read and approved the final version of the manuscript.

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Figure 1 Comparison of the mean complaint rate (%) of the Cumulative Fatigue Symptoms Index by nap time during night shifts (n = 59). Each item was compared by using the Student's t-test.

Figure 2 Comparison of the mean complaint rate (%) of the Cumulative Fatigue Symptoms Index by nap time after night shifts (n = 58). Each item was compared using the Student's t-test.

Figure 3 Comparison of the mean complaint rate (%) of the Cumulative Fatigue Symptoms Index of the Early Group and the Late Group (n = 29). Each item was compared using the Student's t-test. Early Group: the participants who would take a nap in the morning after a night shift and start their nighttime sleep that night before 00:26; Late Group: the participants who would take a nap in the afternoon after a night shift and start their night-time sleep that night after 00:25.

Table 1 Participants characteristics

Characteristics	Total (n = 61)	Age (years)			P-value
		20s (n = 27)	30s (n = 25)	40s (n = 9)	
Sex					–
Male: N (%)	2 (3.3)	0 (0.0)	1 (1.6)	1 (1.6)	
Female: N (%)	59 (96.7)	27 (44.3)	24 (39.3)	8 (13.1)	
Body Mass Index: kg/m^2	21.5 ± 3.5 (20.7)	20.9 ± 3.4 (20.6)	22.1 ± 3.7 (21.3)	21.5 ± 2.7 (20.6)	0.265
Years of nursing experience	8.7 ± 5.5 (7.5)	4.5 ± 1.6 (4.6)	11.0 ± 3.6 (10.6)	14.6 ± 8.3 (15.4)	<0.001
Years of nursing experience at the affiliated department	2.4 ± 2.0 (1.7)	1.6 ± 1.6 (1.2)	3.2 ± 2.1 (2.5)	2.8 ± 1.9 (2.4)	0.001
Child rearing or care: N (%)	8 (12.3)	0 (0.0)	6 (9.8)	0 (0.0)	–
Night shifts during the study period: times	1.6 ± 0.6 (2.0)	1.6 ± 0.6 (2.0)	1.6 ± 0.6 (2.0)	1.7 ± 0.7 (2.0)	0.886
Commuting time: min	31.9 ± 16.3 (30.0)	31.5 ± 15.8 (30.0)	32.9 ± 19.2 (30.0)	30.0 ± 8.3 (30.0)	0.997
Overtime h/month: N (%)					
< 10hr	40 (65.6)	17 (27.9)	16 (26.2)	7 (11.5)	0.704
10hr≤	21 (34.4)	10 (16.4)	9 (14.8)	2 (3.3)	
Medications: N (%)					–
Yes	6 (9.8)	2 (3.3)	2 (3.3)	2 (3.3)	
No	55 (90.2)	25 (41.0)	23 (37.7)	7 (11.5)	
Alcohol consumption: times during study	1.2 ± 1.9（0.0）	1.0 ± 1.8 (0.0)	1.3 ± 2.0 (0.0)	1.4 ± 2.3 (0.0)	0.288
Chronotype: N (%)					–
Moderately morning type	4 (6.5)	0 (0.0)	4 (6.6)	0 (0.0)	
Moderately evening type	12 (19.7)	8 (13.1)	3 (4.9)	1 (1.6)	
Intermediate type or neither type	45 (73.8)	19 (31.1)	18 (29.5)	8 (13.1)	

Data are presented as N (%) or the mean ± standard deviation (median). The chronotype preference was verified using the Morningness-Eveningness Questionnaire.

Table 2 Comparison of sleep, subjective feelings of fatigue, and cumulative fatigue by age

Variable	Total (n = 49)			Age (years) 20s (n = 21)			30s (n = 19)			40s (n = 9)			P-value
Sleep													
TST (h)	8.3	± 1.4	(8.1)	8.6	± 1.3	(8.5)	7.8	± 0.9	(7.8)	8.7	± 2.0	(8.2)	0.053
SE (%)	96.1	± 2.3	(96.2)	96.5	± 1.8	(96.2)	95.5	± 2.7	(95.9)	96.4	± 2.5	(96.6)	0.659
SOL (min)	16.1	± 10.3	(14.6)	17.3	± 13.3	(14.6)	15.2	± 6.4	(14.6)	14.9	± 10.0	(10.5)	0.870
WASO (min)	14.0	± 8.7	(12.1)	13.2	± 7.9	(10.1)	15.0	± 9.8	(12.4)	13.6	± 9.0	(14.8)	0.919
Stime of main sleep	00:30	± 1:03	(00:29)	01:00	± 0:49	(01:08)	00:12	± 1:08	(00:10)	23:58	± 0:54	(00:09)	0.015 *
Etime of main sleep	8:14	± 1:16	(8:17)	8:48	± 1:11	(8:50)	8:01	± 1:20	(8:25)	7:25	± 0:39	(7:34)	0.009 **
LSEP (times)	2.5	± 1.4	(2.2)	2.4	± 1.3	(2.2)	2.1	± 1.4	(1.9)	3.3	± 1.5	(3.6)	0.076
LGSEP (h)	3.4	± 1.2	(3.3)	3.7	± 1.1	(3.3)	3.1	± 1.4	(3.1)	3.4	± 1.0	(3.7)	0.243
Subjective feelings of fatigue													
Before	41.8	± 14.2	(39.0)	41.7	± 12.52	(39.8)	42.3	± 17.52	(36.4)	42.6	± 11.7	(39.0)	0.856 *** *** **
After	48.0	± 15.2	(45.7)	48.2	± 14.85	(45.7)	48.2	± 17.67	(43.0)	48.3	± 9.9	(48.0)	0.828
Cumulative fatigue													
Depressive feelings	29.7	± 23.5	(22.2)	30.7	± 25.6	(18.5)	29.2	± 21.2	(22.2)	28.4	± 25.5	(22.2)	0.926
Anxiety	26.1	± 23.4	(18.2)	29.7	± 27.7	(18.2)	20.9	± 16.6	(18.2)	28.6	± 25.4	(27.3)	0.748
Decreased vitality	34.7	± 30.2	(29.6)	34.9	± 34.4	(25.9)	32.4	± 24.1	(29.6)	39.1	± 34.4	(33.3)	0.918
Irritability	20.8	± 22.5	(14.3)	19.5	± 24.1	(4.8)	20.8	± 22.5	(14.3)	23.8	± 20.5	(23.8)	0.698
Unwillingness to work	26.5	± 25.2	(20.5)	24.7	± 26.3	(12.8)	27.3	± 25.7	(28.2)	29.1	± 24.0	(30.8)	0.883
General fatigue	40.0	± 21.7	(36.7)	41.7	± 23.5	(40.0)	37.0	± 19.1	(36.7)	42.2	± 24.4	(46.7)	0.862
Chronic fatigue sign	50.8	± 26.0	(45.8)	54.2	± 29.0	(50.0)	47.4	± 24.1	(41.7)	50.0	± 24.7	(50.0)	0.647
Physical disorders	21.8	± 17.1	(19.0)	22.0	± 19.8	(14.3)	19.5	± 14.3	(19.0)	25.9	± 16.9	(23.8)	0.620

*P <0.05, **P < 0.01, and ***P <0.001. Kruskal-Wallis test, post-hoc test, Wilcoxon signed-rank test. The data are presented as mean ± standard deviation (median). Etime, the average of the ending time of the main sleep in the study period; LGSEP, the duration of the longest sleep episode; LSEP, a long sleep episode (≤5 min) in an activity time interval; SE, sleep efficiency (100 × Sleep min/[sleep onset–sleep offset duration]); SOL, sleep onset latency; Stime, the average of the starting time of the main sleep in the study period; subjective feelings of fatigue "before," the beginning of work and the waking time on days off; subjective feelings of fatigue "after," the end of working and bedtime; TST, total sleep time; WASO, wake min during the sleep onset–sleep offset interval.

Table 3 Ratio of napping before, during, and after night shifts

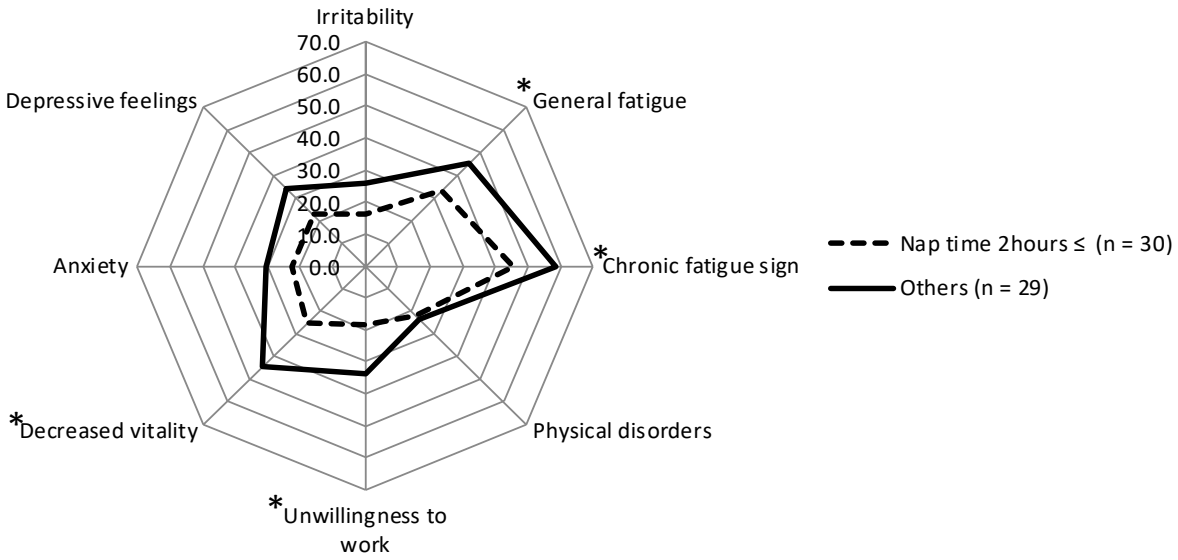
Age (years)	Before night shift: Total nap a.m. nap/p.m. nap	Before night shift: No nap	Age (years)	During night shift: Nap 2hr. ≤/< 2hr.	During night shift: No nap	Age (years)	After night shift: Total nap a.m. nap/p.m. nap	After night shift: No nap
Total (*n* = 59)	23 (39.0)	36 (61.0)	Total (*n* = 59)	54 (91.5)	5 (8.5)	Total (*n* = 58)	52 (89.7)	6 (10.3)
	16 (27.1) /7 (11.9)	–		30 (50.8) / 24 (40.7)	–		19 (32.8) / 33 (56.9)	–
20s (*n* = 26)	7 (26.9)	19 (73.1)	20s (*n* = 26)	24 (92.3)	2 (7.7)	20s (*n* = 25)	20 (80.0)	5 (20.0)
	2 (7.7) /5 (19.2)	–		13 (50.0) /11 (42.3)	–		7 (28.0) /13 (52.0)	–
30s (*n* = 24)	13 (54.2)	11 (45.8)	30s (*n* = 24)	22 (91.7)	2 (8.3)	30s (*n* = 25)	24 (96.0)	1 (4.0)
	11 (45.8) /2 (8.3)	–		12 (50.0) /10 (41.7)	–		9 (36.0) /15 (60.0)	–
40s (*n* = 9)	3（33.3）	6 (66.7)	40s (*n* = 9)	8 (88.9)	1 (11.1)	40s (*n* = 8)	8 (100.0)	0 (0.0)
	3 (33.3) /0 (0.0)	–		5 (55.6) /3 (33.3)	–		3 (37.5) /5 (62.5)	–

Data are presented as N (%).

Table4 Comparison of sleep and nap by subjective fatigue degree

Variable		Subjective feelings of fatigue†		
		High Group (n = 25)	Low Group (n = 24)	P-value
Age: N (%)		20s = 11 (44.0)	20s = 10 (41.7)	—
		30s = 9 (36.0)	30s = 10 (41.7)	—
		40s = 5 (20.0)	40s = 4 (16.7)	—
TST (h)		8.6 ± 1.6	8.0 ± 1.0	0.082
SE (%)		96.4 ± 2.5	95.8 ± 2.2	0.387
SOL (min)		14.6 ± 8.7	17.6 ± 11.8	0.326
WASO (min)		12.5 ± 8.9	15.5 ± 8.4	0.235
Stime of main sleep		0:37 ± 1:06	0:22 ± 0:59	0.412
Etime of main sleep		8:16 ± 1:03	8:13 ± 1:30	0.885
LSEP (times)		2.7 ± 1.5	2.2 ± 1.3	0.198
LGSEP (h)		3.6 ± 1.5	3.2 ± 1.0	0.267
Starting time of sleep				
Night after a night shift (n =56)	≤ 00:25	8 (27.6)	16 (59.3)	0.017
	00:25 <	21 (72.4)	11 (40.7)	
Night before a day shift (n = 61)	≤ 00:25	19 (61.3)	20 (66.7)	0.662
	00:25 <	12 (38.7)	10 (33.3)	
Nap				
Before a night shift (n = 59)	Nap	13 (43.3)	10 (34.5)	0.486
	No nap	17 (56.7)	19 (65.5)	
During a night shift (n = 59)	Nap time 2h ≤	13 (43.3)	17 (58.6)	0.240
	Others	17 (56.7)	12 (41.4)	
After a night shift (n = 58)	Nap in a.m.	8 (27.6)	11 (37.9)	0.401
	Others	21 (72.4)	18 (62.1)	
Starting time of night sleep after night shifts and the nap time after night shifts (n = 29)	Early Group	3 (17.6)	5 (41.7)	0.158
	Late Group	14 (82.4)	7 (58.3)	

†High Group and the Low Group were classified based on the median value. Sleep was analyzed by using the Student's t-test. The start times of the nap and sleep were analyzed by using a Chi-squared test and Fisher's exact test. The data are presented as the mean standard deviation or N (%). Etime, the average ending time of the main sleep in the study period; LGSEP, duration of the longest sleep episodes; LSEP, long sleep episode (≤5 min) in the activity time interval; night before the day shift and night on holiday before the day shift: Early Group, the participants who would take a nap in the morning after a night shift and start their night-time sleep that night before 00:26 hours and Late Group, the participants who would take a nap in the afternoon after a night shift and start their night-time sleep that night after 00:25 hours; SE, sleep efficiency; SOL, sleep onset latency; Stime, the average starting time of the main sleep in the study period; TST, total sleep time; WASO, wake after sleep onset.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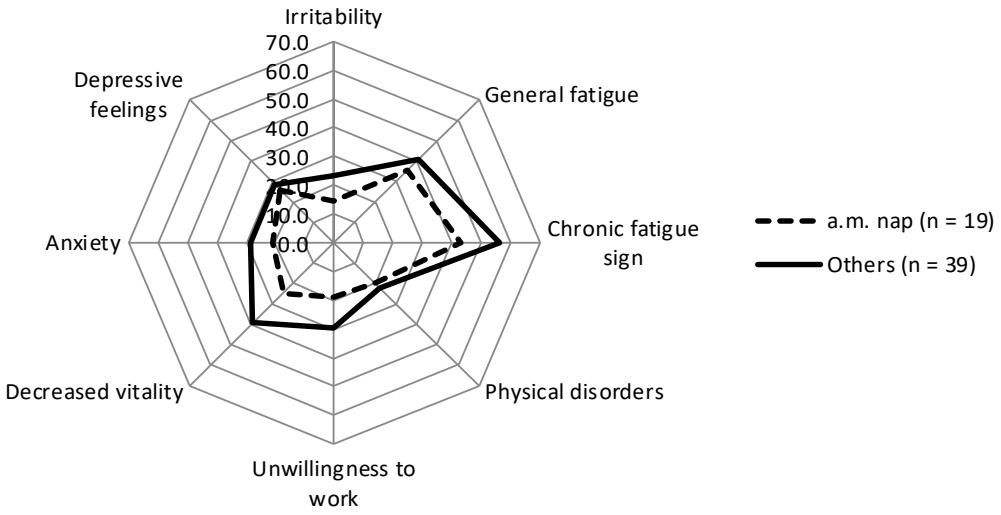
*Decreased vitality
Anxiety
Depressive feelings
Nap time 2hours ≤ (n = 30)
Others (n = 29)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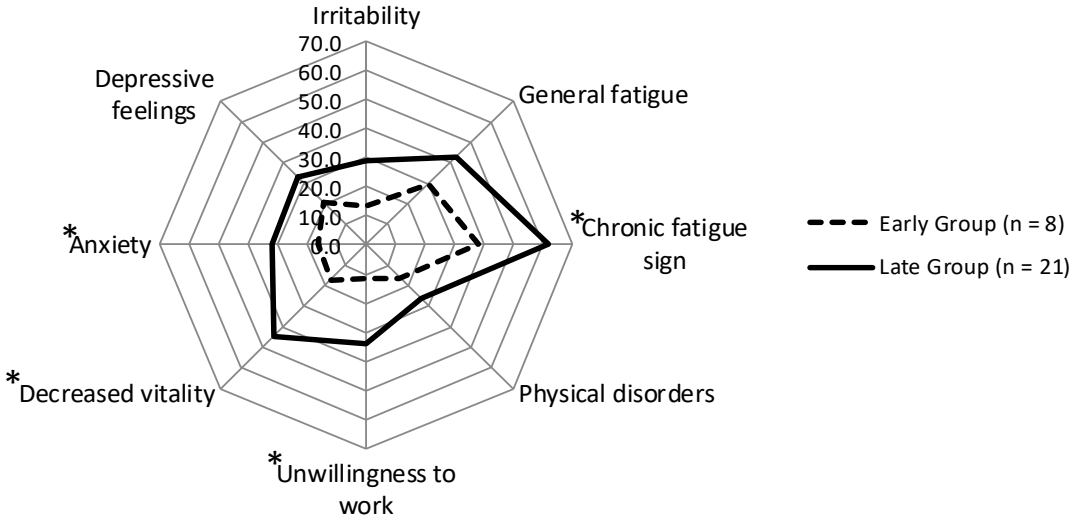
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*Decreased vitality
*Anxiety
Depressive feelings
Early Group (n = 8)
Late Group (n = 21)