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Utility of a Wearable Tracker to Assess Sleep Quality in Nurses and Their Spouses: A Prospective Cohort Study

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Abstract

Introduction: Sleep disturbances among nurses engaged in night duty and their spouses need to be improved to ensure their ability to provide care and perform daily tasks. Therefore, an objective investigation is needed to establish a sleep improvement strategy.

Objective: To investigate the utility of a sleep tracker to assess sleep quality in nurses and spouses.

Method: Nurses ($n = 30$) and spouses ($n = 30$) wore a sleep tracker for 14 days to investigate sleep scores. Sleep quality and number of steps were evaluated by Fitbit. They responded to the Richards-Campbell Sleep Questionnaire and Pittsburgh Sleep Quality Index. A multiple regression analysis was performed to identify the factors affecting sleep quality.

Results: Factors affecting sleep scores in nurses were hypnotic medication, night duty, and steps, while those in spouses were mental instability, hypnotic medication, alcohol, night duty, and steps. Factors affecting the Richards-Campbell Sleep Questionnaire in nurses were household chores, night duty, and steps, while those in spouses were hypnotic medication and steps.

Conclusion: The sleep quality of nurses was affected by household chores, hypnotic medication, night duty, and steps. Besides the factors of nurses, spouses were affected by mental instability and alcohol. Night duty affected negativity in both nurses and spouses. Steps exerted positive effects in both the sleep tracker and the Richards-Campbell Sleep Questionnaire. The sleep tracker may be useful for identifying factors that improve sleep quality.

Keywords

hypnotic medication, physical activity, night shift work, sleep quality, wearable electronic devices

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Introduction

Sleep disorders are common in nurses worldwide because they must provide 24-hour care to patients (D'Ettorre et al., 2020; Geiger-Brown et al., 2012; Zdanowicz et al., 2020). Night duty (ND) has been shown to suppress the secretion of melatonin, which prolongs sleep induction and shortens the period of deep sleep (Leung et al., 2016; Resuehr et al., 2019). Sleep disturbances have been reported in approximately 40% of nurses who engage in ND (Deng et al., 2020; Pang et al., 2021). While the number of night shift nurses is increasing in Europe and the US, many nurses engage in a mix of day duty and ND in Japan (Kubo et al., 2022). Therefore, insomnia among nurses has reached a severe level in Japan (Asaoka et al., 2013). Poor sleep quality

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results in sleep-related symptoms, such as difficulties with the induction of sleep, awakening during the night, waking early in the morning, and insomnia (Medic et al., 2017). Insomnia decreases daily activity with systemic symptoms, such as daytime fatigue, low motivation, poor concentration, and reduced appetite (Krystal et al., 2019). It also increases the risk of developing cardiovascular diseases, metabolic diseases, mental disorders, poor reproductive function, and cancers (Medic et al., 2017). Furthermore, insomnia decreases decision-making skills and increases medical accidents by nurses (Caruso, 2014; Scott, 2000). Therefore, assessments of and improvements in sleep quality are essential to ensure the provision of good healthcare service by nurses.

Sleep quality differs between married and single nurses and is slightly worse in the former (Berkman et al., 2015; Jung, 2020; Liu et al., 2020). Domestic stress in the home may reduce the sleep quality of married nurses and their spouses (AlAzzam et al., 2017; Netemeyer et al., 1996). Therefore, the sleep conditions of nurses and their spouses need to be investigated. Various studies have attempted to evaluate sleep quality. Although polysomnography (PSG) is the gold standard assessment for sleep, it requires specific equipment with multiple electric cords during sleep (Jafari & Mohsenin, 2010). Therefore, it is challenging to use PSG in routine tests. The objective evaluation of sleep quality, primarily the relationship between nurses and their spouses, has yet to be performed. The Richards-Campbell Sleep Questionnaire (RCSQ) and Pittsburgh Sleep Quality Index (PSQI) have been employed as alternatives to assess sleep quality. However, these questionnaires analyze subjective sleep satisfaction and do not measure sleep quality quantitatively. In addition, the relationship between subjective sleep questionnaires and objective assessments using sleep trackers is unclear (Cudney et al., 2022).

Various wearable devices have recently been developed to assess physical activity, including quantitative and qualitative sleep assessments. Fitbit® (Fitbit, Inc., San Francisco, USA) is a watch-type sleep tracker that monitors biometric information, including breathing rate, heart rate variability, physical activity, and number of steps. A scoring algorithm based on body movement and heart rate variability enables the measurement of sleep parameters, such as sleep scores, total sleep time (TST), wake after sleep onset (WASO), the number of awakenings, time in bed, and sleep stages (Haghayegh et al., 2020). According to a 2019 survey, there are more than 25 million users of Fitbit worldwide. The sleep tracker may non-invasively collect continuous data for a long-term investigation. Fitbit may also be used to simultaneously assess the sleep quality and daily activities of nurses and their spouses. Therefore, the first aim of the present study was to investigate the utility of a sleep tracker for assessing the sleep quality of nurses engaged in ND and their spouses. The second aim was to elucidate the relationship between Fitbit data and subjective sleep questionnaires, such as RCSQ and PSQI. The third aim was to find the relations between sleep quality and daily activities.

Review of Literature

Sleep disturbances are defined as a persistent difficulty with sleep initiation, duration, or consolidation that occurs despite adequate opportunity and circumstances for sleep and results in concern, dissatisfaction, or perceived daytime impairment, such as fatigue, decreased mood or irritability, general malaise, or cognitive impairment (Sateia, 2014). The prevalence of sleep disturbances among nurses was shown to be 30–50% in both the US and Japan (Kageyama et al., 2001; Lockley et al., 2007; Stimpfel et al., 2020). Sleep quality is associated with sex, age (Ohayon et al., 2004), the use of hypnotic medication, the habitual consumption of alcohol, caffeine consumption, smoking habit, daytime activities (Drake et al., 2013; Feige et al., 2006; Ohayon et al., 2004), and mental instability, including anxiety, depression, and stress (Krystal, 2012). In the case of nurses, sleep quality was also shown to be directly affected by the conditions of their spouses at home (Ebrahimian et al., 2023). On the other hand, it was deteriorated by ND, the duration of work, and interpersonal relationships in the hospital (Lu et al., 2012).

A sleep assessment is divided into two methods using questionnaires for a subjective assessment and sleep trackers for objective measurements. Sleep questionnaires have participants answer many questions and researchers assess bias (Leong et al., 2020). Sleep trackers are powerful technologies that have become increasingly small and smart, and automatic measurements are possible simply by wearing the device (Godfrey et al., 2008). Therefore, the present study aimed to assess sleep quality using a sleep tracker.

Method

Design

This prospective cohort study design was performed between August 2022 and September 2023. Three hospitals in Japan were included in the present study to assess the sleep quality of nurses engaged in ND and their spouses. Nurses were recruited from all medical departments, including outpatient and inpatient wards.

Research Questions

1. Is there any difference in sleep quality among nurses and their spouses?
2. What factors affect sleep quality in nurses and their spouses?
3. Does Fitbit provide similar information on the sleep quality of nurses and their spouses as RCSQ or PSQI?

Sample

Thirty couples were recruited for this prospective cohort study. Participants were nurses who engaged in ND at least once a week. The rotating shifts of participants in the present study are shown in Supplement Table 1. All nurses included in this study were engaged in two work shifts, with eight hours on the day shift and 16 hours on ND. ND started at 5.00 pm and finished at 9.00 am.

The sample size was calculated using a multiple linear regression model with fixed variables by G*power software (ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). In a previous study, R^2 was 0.41 in the nurses' sleep efficiency model with four predictor variables; therefore, the effect size in the present study was calculated as 0.34 (Shin & Kim, 2021). The sample size was calculated as 29 cases from an estimate of 0.05 for an alpha error and 0.85 for power. Accounting for dropouts, the required sample size was 30 cases each for nurses and their spouses.

Inclusion/Exclusion Criteria

Inclusion criteria were nurses who lived with their spouses and engaged in ND during the study period. Participants were given instructions on how to use Fitbit and only included those confident in operating the sleep tracker (Fitbit). Exclusion criteria were an inability to wear the sleep tracker due to allergies or an inability to sleep when the tracker was worn on the wrist.

Procedure

All investigations were performed in the homes of nurses. Participants installed the sleep tracker (Fitbit App®) application on their mobile phones and registered for an individual account. Participants wore the sleep tracker on their wrists for 14 days during the study. The application automatically collected data from the sleep tracker to the mobile phone. Participants charged sleep trackers during the weekend once a week. RCSQ was self-checked on the five-item questionnaire to measure sleep awareness every morning. PSQI was also performed on the morning of the 14th day of the investigation.

Sleep Tracker Measurements

Fitbit has a three-axis accelerometer, altimeter, vibration motor, and optical heart rate monitor (Haghayegh et al., 2020). The tracker records the sleep status, such as the sleep score, TST, WASO, the number of awakenings, time in bed, rapid eye movement (REM) sleep time, shallow sleep time, and deep sleep time. Daily activities, including number of steps, were recorded by the tracker. The sleep score is calculated with a specific algorithm based on TST, the percentages of deep sleep and REM sleep, the difference between resting and sleep heart rates, and the number of awakenings (Wallace et al., 2022). Sleep scores show the grade of sleep quality on a scale of 0–100: very good is 90–100, moderate is 80–89, slightly low is 60–79, and low is below 60. TST is the time from sleep onset to awakening, excluding the time of awakening. WASO is the time awake after sleep onset (Brupbacher et al., 2019). Shallow sleep is the first stage of sleep, followed by deep sleep and REM sleep. Shallow sleep falls under the sum of the N1 and N2 stages measured with the PSG, and deep sleep falls under the sum of the N3 and N4 stages (Haghayegh et al., 2019). The reliability of Fitbit data has been demonstrated in previous studies (Lee et al., 2017).

Questionnaire for the Sleep Assessment

Since the relationship between RCSQ or PSQI and Fitbit sleep data is unclear, both questionnaires were used in the present study. The Japanese version of RCSQ evaluated participants' sleep quality (Murata et al., 2019). This instrument includes a five-item self-reported questionnaire to assess perceived sleep depth, sleep latency (time to fall asleep), the number of awakenings, sleep efficiency (percentage of time awake), and sleep quality (Murata et al., 2019; Richards et al., 2000). Participants scored each item on a paper-based visual analog scale. The mean of the five items ranged between 0 and 100, with higher scores representing an overall perception of better sleep. RCSQ was proven to be reliable as a practical, non-invasive tool for sleep perception in ICU patients and the general population (Ritmala-Castren et al., 2022). The Japanese version of PSQI evaluated total sleep quality for the study period (Doi, Minowa, Uchiyama, et al., 2000). The questionnaire has 19 items divided into seven components: subjective sleep quality, sleep latency, duration, habitual sleep efficiency, sleep disturbances, the use of sleeping medication, and daytime dysfunction in the past month (Buysse et al., 1989). Each component ranges between 0 and 3, generating a global score of 0–21. According to global standards, we defined a score >5.5 as poor sleep quality (Buysse et al., 2008; Fabbri et al., 2021). PSQI is a reliable subjective sleep measurement scale with proven internal consistency, high sensitivity, and high specificity (Doi, Minowa, Okawa, Uchiyama, et al., 2000).

Other Variables

Participants answered demographic characteristics questionnaires on the last day of the study. The questionnaire was designed based on previous studies and consisted of age (years), sex (male or female), height (cm), weight (kg), mental instability (yes or no), use of hypnotic medication (yes or no), number of children, spouse in the bedroom (same or separate), household chores (yes or no), habitual consumption of alcohol (yes or no), caffeine consumption

Table 1. Demographics of Nurses and Their Spouses.

Characteristics		Spouses ($n = 30$)	Nurses ($n = 30$)	x^2	p-value
	Mean ± SD or %		Mean ± SD or %		
Age (years)	44.23 ± 10.70		43.20 ± 7.96	–	.67[a]
Sex	Male	86.7	13.3	30.00	<.001[c*]
	Female	13.3	86.7		
Height (cm)	168.27 ± 4.65		164.50 ± 8.00	–	.030[a*]
Weight (kg)		64.83 ± 5.14	63.60 ± 8.02	–	.28[b]
Mental instability	Yes	20.0	13.3	2.60	.11[c]
	No	80.0	86.7		
Use of hypnotic medication	Yes	43.3	23.3	11.94	<.001[c*]
	No	56.7	76.7		
Number of children		0.90 ± 1.12	0.90 ± 1.12	–	1
Spouse in the bedroom	Same	86.7	86.7	0.00	1
	Separate	13.3	13.3		
Household chores	Yes	66.7	76.7	4.57	.033[c*]
	No	33.3	23.3		
Habitual consumption of alcohol	Yes	63.3	56.7	1.82	.18[c]
	No	36.7	43.3		
Caffeine consumption at night	Yes	26.7	46.7	1.10	.29[c]
	No	73.3	53.3		
Smoking habit	Yes	43.3	16.7	3.29	.070[c]
	No	56.7	83.3		
Days on night duty (2 weeks)		–	2.47 ± 0.82	–	–
Years in the occupation		–	20.37 ± 8.94	–	–
Years at the department		–	5.77 ± 3.71	–	–
Number of steps	7942.78 ± 1233.21		7019.26 ± 1092.00	–	.001[b*]
Sleep scores		80.02 ± 3.67	77.67 ± 2.73	–	.005[b*]
Total sleep time (min)	444.69 ± 48.10		411.83 ± 40.11	–	.008[b*]
Wake after sleep onset (min)		62.62 ± 5.45	58.84 ± 8.19	–	.12[b]
Number of awakenings		33.66 ± 4.04	30.99 ± 3.52	–	.008[a*]
Time in bed (min)	507.31 ± 52.85		470.67 ± 46.85	–	.011[b*]
REM sleep time (min)	79.98 ± 16.04		69.85 ± 10.61	–	.004[b*]
Shallow sleep time (min)	287.88 ± 24.65		269.09 ± 27.83	–	.001[b*]
Deep sleep time (min)	76.84 ± 11.38		72.89 ± 7.58	–	.15[b]
RCSQ		54.66 ± 3.35	53.04 ± 2.39	–	.019[b*]
PSQI		6.17 ± 4.67	5.70 ± 3.82	–	.77[b]

REM: rapid eye movement, RCSQ: Richards-Campbell sleep questionnaire, PSQI: Pittsburgh sleep quality index. [a]The Student's t-test. [b]The Wilcoxon signed-rank test. [c]The chi-square test. *$p < .05$.

at night (yes or no), smoking habit (yes or no), days on ND, years in the occupation, and years at the department (Drake et al., 2013; Ebrahimian et al., 2023; Feige et al., 2006; Krystal, 2012; Lu et al., 2012; Ohayon et al., 2004). "Mental instability" was assessed based on whether participants experienced mental instability, such as anxiety or depression, during the study period (Krystal, 2012). "Habitual consumption of alcohol" was defined as participants consuming alcohol at least three days per week (Feige et al., 2006).

Statistical Analysis

Data were analyzed using JMP Pro® (Verision15; SAS Institute Inc., Cary, USA). The demographics of nurses and their spouses were compared. All continuous variables were examined for normality. Data with normal distributions were examined using the Student's t-test (independent sample t-test), while those with skewed distributions were tested by the Wilcoxon signed-rank test. The results of the Student's t-test and the Wilcoxon signed-rank test were shown by mean ± standard divisions. Dichotomous variables were compared by the chi-square test. The results of the chi-square tests were shown by percentages.

A univariate analysis was performed with objective variables, such as the sleep score on Fitbit, RCSQ, and PSQI before the multiple regression analysis. Independent variables were age, sex, height, weight, mental instability, the use of hypnotic medication, number of children, spouse in the bedroom, household chores, habitual consumption of alcohol, caffeine consumption at night, smoking habit, days

on ND, years in the occupation, years at the department, and number of steps. The multiple regression analysis was performed using the forward–backward stepwise selection method on independent variables with significant differences from the univariate analysis. All analyses were performed with $p < .05$, indicating a significant difference.

A subgroup analysis of the sleep status (Fitbit and RCSQ scores) was used to investigate the effects of ND on the sleep quality of nurses and their spouses. Data on nurses were compared between the night after ND and other nights. Data on spouses were also compared among the night during ND, the night after ND, and other nights.

Ethical Consideration

All participants provided their written informed consent prior to registration. Participants were given the opportunity to withdraw from the study at any time. The questionnaire was kept short to limit the risk of fatigue and exhaustion among participants. All information was changed to be anonymous, and confidentiality was maintained at all stages of the study. All data was handled carefully and stored on an encrypted device. The Ethical Committee approved the present study, and a Clinical Trial was used for protocol registration. All human subjects' rights were protected by our protocol.

Results

Sample Characteristics

The present study was completed according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (Elm et al., 2014). The demographics of enrolled nurses ($n = 30$) and their spouses ($n = 30$) are shown in Table 1. These demographics were compared. Variables with normal distributions (age, height, and the number of awakenings) were examined using the Student's *t*-test. Variables with skewed distributions (weight, the number of steps, sleep scores, total sleep time, wake after sleep onset, time in bed, REM sleep time, shallow sleep time, deep sleep time, RCSQ, and PSQI) were tested by the Wilcoxon signed-rank test. Dichotomous variables (sex, mental instability, the use of hypnotic medication, household chores, habitual consumption of alcohol, caffeine consumption at night, and smoking habit) were compared by the chi-square test. Sex in male (86.7% vs. 13.3%, $p < .001$), height (168.27 ± 4.65 vs. 164.50 ± 8.00, $p = .030$), the use of hypnotic medication (43.3% vs. 23.3%, $p < .001$), household chores (66.7% vs. 76.7%, $p = .033$), and the number of steps (7942.78 ± 1233.21 vs. 7019.26 ± 1092.00, $p = .001$) significantly differed between nurses and their spouses. Regarding the sleeping status, sleep scores (80.02 ± 3.67 vs. 77.67 ± 2.73, $p = .005$), TST (444.69 ± 48.10 vs. 411.83 ± 40.11, $p = .008$), the number of awakenings (33.66 ± 4.04 vs. 30.99 ± 3.52, $p = .008$), time in bed (507.31 ± 52.85 vs. 470.67 ± 46.85, $p = .011$), REM sleep time (79.98 ± 16.04 vs. 69.85 ± 10.61, $p = .004$), shallow sleep time (287.88 ± 24.65 vs. 269.09 ± 27.83, $p = .001$), and RCSQ (54.66 ± 3.35 vs. 53.04 ± 2.39, $p = .019$) also significantly differed between nurses and their spouses. None of the spouses engaged in healthcare work or night work. The average duration of experience in the occupation was more than twenty years and days on ND were 2.47 ± 0.82 in 2 weeks.

The sleeping status of nurses and their spouses on and off ND is shown in Supplement Tables 2 and 3. In nurses, the sleep score (78.8 ± 2.5 vs. 74.0 ± 2.9, $p < .001$), TST (431.4 ± 42.8 vs. 343.2 ± 37.3, $p < .001$), WASO (62.1 ± 9.3 vs. 47.1 ± 10.9, $p < .001$), the number of awakenings (32.5 ± 3.7 vs. 25.2 ± 4.0, $p < .001$), time in bed (493.5 ± 50.3 vs. 390.3 ± 47.0, $p < .001$), REM sleep time (74.3 ± 11.1 vs. 56.7 ± 15.7, $p < .001$), shallow sleep time (281.4 ± 29.7 vs. 221.9 ± 37.0, $p < .001$), deep sleep time (75.7 ± 9.0 vs. 64.5 ± 15.3, $p = .001$), and RCSQ (53.6 ± 2.5 vs. 50.9 ± 1.0, $p < .001$) significantly differed between usual nights and nights after ND. In spouses, the sleep score (79.7 ± 3.5 vs. 83.4 ± 5.9 vs. 77.8 ± 3.7, $p < .001$), TST (442.1 ± 49.4 vs. 472.8 ± 68.4 vs. 423.5 ± 57.3, $p = .006$), time in bed (504.9 ± 55.0 vs. 535.9 ± 76.8 vs. 485.2 ± 65.5, $p = .015$), REM sleep time (78.8 ± 15.8 vs. 91.8 ± 27.5 vs. 70.9 ± 18.4, $p = .001$), shallow sleep time (286.5 ± 26.9 vs. 302.8 ± 42.7 vs. 276.8 ± 35.2, $p = .020$), and RCSQ (54.0 ± 3.2 vs. 59.0 ± 6.4 vs. 52.8 ± 3.0, $p < .001$) significantly differed between usual nights, nights on ND, and nights after ND. *Ad hoc* tests on spouses revealed significant differences between any pair of the three types of nights.

Factors Affecting Sleep Scores in Nurses

The univariate regression analysis of nurses identified seven independent variables affecting sleep scores: sex ($B = -1.29$, 95% CI: −2.27 to −0.31, $p = .012$), height ($B = 0.13$, 95% CI: 0.01 to 0.25, $p = .033$), mental instability ($B = -1.82$, 95% CI: −3.17 to −0.46, $p = .010$), the use of hypnotic medication ($B = -1.70$, 95% CI: −2.73 to −0.66, $p = .002$), household chores ($B = -1.59$, 95% CI: −2.65 to −0.53, $p = .005$), days on ND ($B = -1.62$, 95% CI: −2.75 to −0.50, $p = .006$), and the number of steps ($B = 0.002$, 95% CI: 0.002 to 0.003, $p < .001$) (Table 2). These independent variables were used in the multiple regression analysis. The forward stepwise selection method identified the following three factors after adjustments for confounders: the use of hypnotic medication ($B = -0.85$, 95% CI: −1.52 to −0.18, $p = .015$), days on ND ($B = -0.81$, 95% CI: −1.50 to −0.12, $p = .023$), and the number of steps ($B = 0.002$, 95% CI: 0.001 to 0.002, $p < .001$). Adjusted power in the post hoc test was 0.99 for hypnotic medication, 0.60 for days on ND, and 0.52 for the number of steps. Multicollinearity appeared to be low because each variance inflation factor (VIF) was 1.32 for the use of hypnotic medication, 1.31 for days on ND, and 1.56 for the number of steps. Adjusted R^2 was 0.77; therefore, the

Table 2. Multiple Regression Analysis of Sleep Scores in Nurses.

$n = 30$	Univariate analysis			Forward stepwise selection method			
Characteristics	*B*	95% CI	*p*-value	*B*	95% CI	*p*-value	VIF
Age (years)	−0.04	−0.17 to 0.09	.54				
Sex	−1.29	−2.27 to −0.31	.012*	–	–	.72	–
Height (cm)	0.13	0.01 to 0.25	.033*	–	–	.89	–
Weight (kg)	0.12	−0.01 to 0.24	.06				
Mental instability	−1.82	−3.17 to −0.46	.010*	–	–	.98	–
Use of hypnotic medication	−1.70	−2.73 to −0.66	.002*	−0.85	−1.52 to −0.18	.015*	1.32
Number of children	−0.63	−1.54 to 0.28	.16				
Spouse in the bedroom	−1.39	−2.81 to 0.04	.06				
Household chores	−1.59	−2.65 to −0.53	.005*	–	–	.15	–
Habitual consumption of alcohol	0.82	−0.17 to 1.82	.10				
Caffeine consumption at night	−0.02	−1.06 to 1.02	.97				
Smoking habit	−0.96	−2.30 to 0.38	.15				
Days on night duty	−1.62	−2.75 to −0.50	.006*	−0.81	−1.50 to −0.12	.023*	1.31
Years in the occupation	−0.03	−0.15 to 0.08	.56				
Years at the department	0.17	−0.11 to 0.44	.23				
Number of steps	0.002	0.002 to 0.003	<.001*	0.002	0.001 to 0.002	<.001*	1.56

Adjustment R^2 is 0.77; the Durbin–Watson ratio is 1.50.
B: Partial regression coefficient, 95% CI: 95% confidence interval of *B*, VIF: variance inflation factor.
*$p < .05$.

Table 3. Multiple Regression Analysis of Sleep Scores in Spouses.

$n = 30$	Univariate analysis			Forward stepwise selection method			
Characteristics	*B*	95% CI	*p*-value	*B*	95% CI	*p*-value	VIF
Age (years)	−0.03	−0.16 to 0.11	.70				
Sex	1.45	0.08 to 2.82	.039*	–	–	.31	–
Height (cm)	−0.05	−0.36 to 0.25	.73				
Weight (kg)	−0.24	−0.50 to 0.02	.07				
Mental instability	−2.73	−4.12 to −1.34	<.001*	−0.86	−1.69 to −0.04	.041*	1.63
Use of hypnotic medication	−2.55	−3.55 to −1.54	<.001*	−1.34	−2.08 to −0.60	.001*	1.99
Number of children	−0.04	−1.30 to 1.23	.95				
Spouse in the bedroom	−1.74	−3.68 to 0.20	.08				
Household chores	0.45	−1.02 to 1.92	.54				
Habitual consumption of alcohol	−1.80	−3.07 to −0.52	.007*	−0.82	−1.54 to −0.10	.028*	1.81
Caffeine consumption at night	−0.24	−1.81 to 1.34	.76				
Smoking habit	−1.03	−2.38 to 0.32	.13				
Days on night duty	−1.77	−3.36 to −0.17	.031*	−0.65	−1.35 to −0.06	.048*	1.21
Number of steps	0.003	0.002 to 0.003	<.001*	0.001	0.001 to 0.002	.002*	1.21

Adjustment R^2 is 0.86; the Durbin–Watson ratio is 1.49.
B: Partial regression coefficient, 95% CI: 95% confidence interval of *B*, VIF: variance inflation factor.
*$p < .05$.

model fits well. The normality of residuals was considered to be random because the Durbin–Watson ratio was 1.50.

Factors Affecting Sleep Scores in Spouses

The univariate regression analysis of spouses identified six independent variables affecting sleep scores: sex ($B = 1.45$, 95% CI: 0.08 to 2.82, $p = .039$), mental instability ($B = -2.73$, 95% CI: −4.12 to −1.34, $p < .001$), the use of hypnotic medication ($B = -2.55$, 95% CI: −3.55 to −1.54, $p < .001$), habitual consumption of alcohol ($B = -1.80$, 95% CI: −3.07 to −0.52, $p = .007$), days on ND ($B = -1.77$, 95% CI: −3.36 to −0.17, $p = .031$), and the number of steps ($B = 0.003$, 95% CI: 0.002 to 0.003, $p < .001$) (Table 3). These six independent variables

were used in a multiple regression analysis. The forward stepwise selection method identified the following five factors after adjustments for confounding factors: mental instability ($B = -0.86$, 95% CI: −1.69 to −0.040, $p = .041$), the use of hypnotic medication ($B = -1.34$, 95% CI: −2.08 to −0.60, $p = .001$), the habitual consumption of alcohol ($B = -0.82$, 95% CI: −1.54 to −0.097, $p = .028$), days on ND ($B = -0.65$, 95% CI: −1.35 to 0.055, $p = .048$), and the number of steps ($B = 0.001$, 95% CI: 0.001 to 0.002, $p = .002$). Adjusted power using the post hoc test was 0.41 for mental instability, 0.91 for the use of hypnotic medication, 0.49 for the habitual consumption of alcohol, 0.31 for days on ND, and 0.87 for the number of steps. Multicollinearity appeared to be low because each VIF was 1.63 for mental instability, 1.99 for the use of hypnotic medication, 1.81 for the habitual consumption of alcohol, 1.21 for days on ND, and 1.21 for the number of steps. Adjusted R^2 was 0.86; therefore, the model fits well. The normality of residuals was considered to be random because the Durbin–Watson ratio was 1.49.

Factors Affecting RCSQ in Nurses

The univariate regression analysis of nurses identified six independent variables affecting RCSQ: sex ($B = -1.09$, 95% CI: −1.96 to −0.22, $p = .015$), height ($B = 0.11$, 95% CI: 0.01 to 0.22, $p = .043$), spouse in the bedroom ($B = -1.76$, 95% CI: −2.91 to −0.61, $p = .004$), household chores ($B = -1.69$, 95% CI: −2.54 to −0.84, $p < .001$), days on ND ($B = -1.67$, 95% CI: −2.60 to −0.75, $p < .001$), and the number of steps ($B = 0.002$, 95% CI: 0.001 to 0.002, $p < .001$) (Table 4). These six independent variables were used in a multiple regression analysis. The forward stepwise selection method identified the following three factors after adjustments for confounders: household chores ($B = -0.76$, 95% CI: −1.39 to −0.14, $p = .018$), days on ND ($B = -0.65$, 95% CI: −1.31 to 0.001, $p = .049$), and the number of steps ($B = 0.001$, 95% CI: 0.001 to 0.002, $p < .001$). Adjusted power using the post hoc test was 0.56 for household chores, 0.37 for days on ND, and 0.99 for the number of steps. Multicollinearity appeared to be low because each VIF was 1.32 for household chores, 1.31 for days on ND, and 1.30 for the number of steps. Adjusted R^2 was 0.74; therefore, the model fits well. The normality of residuals was considered to be random because the Durbin–Watson ratio was 1.48.

Factors Affecting RCSQ in Spouses

The univariate regression analysis of spouses identified eight independent variables affecting RCSQ: sex ($B = 1.55$, 95% CI: 0.34 to 2.76, $p = .014$), weight ($B = -0.29$, 95% CI: −0.51 to −0.06, $p = .014$), mental instability ($B = -1.94$, 95% CI: −3.35 to −0.54, $p = .008$), the use of hypnotic medication ($B = -2.11$, 95% CI: −3.10 to −1.11, $p < .001$), spouse in the bedroom ($B = -2.02$, 95% CI: −3.72 to −0.32, $p = .022$), habitual consumption of alcohol ($B = -1.66$, 95% CI: −2.81 to −0.50, $p = .007$), days on ND ($B = -1.85$, 95% CI: −3.26 to −0.44, $p = .012$), and the number of steps ($B = 0.002$, 95% CI: 0.002 to 0.003, $p < .001$) (Table 5). These eight independent variables were used in a multiple regression analysis. The forward stepwise selection method identified the following two factors after adjustments for confounders: the use of hypnotic medication ($B = -0.73$, 95% CI: −1.39 to −0.078, $p = .030$) and the number of steps ($B = 0.002$, 95% CI: 0.002 to 0.003, $p < .001$). Adjusted power using the post hoc test was 0.48 for the use of hypnotic medication and 0.99 for the number of steps. Multicollinearity appeared to be low because each VIF was 1.41 for the use of hypnotic medication and 1.41 for the number of steps. Adjusted R^2 was 0.81; therefore, the model fits well. The normality of residuals was considered to be random because the Durbin–Watson ratio was 1.35.

Factors affecting PSQI in nurses and their spouses are shown in supplement Tables 4 and 5. The multiple regression analysis of nurses and their spouses identified two factors affecting mental instability and the use of hypnotic medication in PSQI.

Discussion

The present results revealed the factors affecting sleep quality in nurses and their spouses using a sleep tracker. The number of steps positively affected sleep quality in nurses and their spouses. On the other hand, sleep quality was reduced on ND. These results are consistent with previous findings, and, thus, the sleep tracker may be useful for assessing the sleep quality of nurses and their spouses.

Significant differences were observed in the sex of participants. In the present study, 87% of nurses were females, which is in accordance with approximately 90% of nurses being females in the US and Japan (McMillian et al., 2006; Nakata & Miyazaki, 2008). This study also observed significant differences in household chores between nurses and their spouses. Household chores in America are generally shared among partners (Coltrane, 2000). However, Japanese nurses typically manage all household chores (Sakuragi et al., 2022). Since the culture of female inferiority still lingers in Japan, the uneven distribution of household chores between spouses may be a stressor and, thus, affect sleep quality in married female nurses (Hwang & Yu, 2021). Sex differences and household chores have been suggested to affect sleep quality. The use of hypnotic medication in the present study was also higher than previously reported (Izumida et al., 2022; Kodaira & Silva, 2017). In addition, high rates of the habitual consumption of alcohol and smoking may have directly or indirectly affected the results obtained. These backgrounds reflect the social issues nurses encounter in their specific medical field.

Factors affecting sleep quality in nurses were the use of hypnotic medication, days on ND, and the number of steps.

Table 4. Multiple Regression Analysis of RCSQ in Nurses.

$n = 30$	Univariate analysis			Forward stepwise selection method			
Characteristics	*B*	95% CI	*p*-value	*B*	95% CI	*p*-value	VIF
Age (years)	0.002	−0.11 to 0.12	.97				
Sex	−1.09	−1.96 to −0.22	.015*	–	–	.32	–
Height (cm)	0.11	0.01 to 0.22	.043*	–	–	.29	–
Weight (kg)	0.10	−0.01 to 0.21	.07				
Mental instability	−1.03	−2.31 to 0.24	.11				
Use of hypnotic medication	−0.89	−1.91 to 0.12	.08				
Number of children	−0.45	−1.25 to 0.35	.26				
Spouse in the bedroom	−1.76	−2.91 to −0.61	.004*	–	–	.06	–
Household chores	−1.69	−2.54 to −0.84	<.001*	−0.76	−1.39 to −0.14	.018*	1.32
Habitual consumption of alcohol	0.63	−0.26 to 1.51	.16				
Caffeine consumption at night	0.35	−0.55 to 1.25	.43				
Smoking habit	−0.71	−1.90 to 0.47	.23				
Days on night duty	−1.67	−2.60 to −0.75	<.001*	−0.65	−1.31 to −0.01	.049*	1.31
Years in the occupation	−0.01	−0.11 to 0.10	.88				
Years at the department	0.16	−0.08 to 0.40	.19				
Number of steps	0.002	0.001 to 0.002	<.001*	0.001	0.001 to 0.002	<.001*	1.30

Adjustment R^2 is 0.74; the Durbin–Watson ratio is 1.48.
B: Partial regression coefficient, 95% CI: 95% confidence interval of *B*, VIF: variance inflation factor.
*$p < .05$.

Table 5. Multiple Regression Analysis of RCSQ in Spouses.

$n = 30$	Univariate analysis			Forward stepwise selection method			
Characteristics	*B*	95% CI	*p*-value	*B*	95% CI	*p*-value	VIF
Age (years)	−0.03	−0.15 to 0.09	.58				
Sex	1.55	0.34 to 2.76	.014*	–	–	.49	–
Height (cm)	−0.07	−0.35 to 0.21	.60				
Weight (kg)	−0.29	−0.51 to −0.06	.014*	–	–	.21	–
Mental instability	−1.94	−3.35 to −0.54	.008*	–	–	.76	–
Use of hypnotic medication	−2.11	−3.10 to −1.11	<.001*	−0.73	−1.39 to −0.08	.030*	1.41
Number of children	−0.22	−1.37 to 0.93	.70				
Spouse in the bedroom	−2.02	−3.72 to −0.32	.022*	–	–	.14	–
Household chores	0.63	−0.70 to 1.96	.34				
Habitual consumption of alcohol	−1.66	−2.81 to −0.50	.007*	–	–	.17	–
Caffeine consumption at night	−0.05	−1.49 to 1.39	.94				
Smoking habit	−1.10	−2.31 to 0.12	.07				
Days on night duty	−1.85	−3.26 to −0.44	.012*	–	–	.06	–
Number of steps	0.002	0.002 to 0.003	<.001*	0.002	0.002 to 0.003	<.001*	1.41

Adjustment R^2 is 0.81; the Durbin–Watson ratio is 1.35.
B: Partial regression coefficient, 95% CI: 95% confidence interval of *B*, VIF: variance inflation factor.
*$p < .05$.

The number of steps positively improved sleep quality, which is consistent with previous findings (Bisson et al., 2019). On the other hand, the use of hypnotic medication negatively correlated with sleep quality. Hypnotic medication does not always correlate with good sleep quality and may indirectly cause poor sleep quality (Doi, Minowa, Uchiyama, Okawa, 2000; Lin et al., 2022). Therefore, individuals using hypnotic medication with poor sleep quality must consult a mental health specialist.

Mental instability and the habitual consumption of alcohol were identified as factors affecting sleep scores in spouses. Previous studies demonstrated that mental health was strongly associated with sleep quality (Clement-Carbonell et al., 2021; Scott et al., 2021). Alcohol may reduce sleep latency in a manner that is dependent on the amount consumed (Roehrs & Roth, 2001). The habitual consumption of alcohol is associated with the rapid development of tolerance and, thus, needs to be safely tapered (Sharma et al.,

2022). Alcohol prevents good sleep through multiple mechanisms disturbing the electrophysiological architecture, causing insomnia, circadian rhythm disturbances, and a short sleep time (He et al., 2019). A community-based study showed that higher alcohol consumption was associated with poor sleep quality and a short sleep time (Zheng et al., 2021). Therefore, mental instability and alcohol consumption in spouses may reflect a social issue in the homes of nurses in Japan.

ND had a negative impact on the sleep quality of nurses. Furthermore, sleep quality on the night after ND was poorer than usual. ND disturbs the circadian rhythm, which leads to poor sleep quality (Reid & Abbott, 2015). This disruption of the circadian rhythm may persist for a number of days after ND. The present results also showed that ND negatively affected the sleep quality of spouses. Family members affect each other physically, psychologically, and emotionally (Gunn & Eberhardt, 2019). The sleep quality of spouses improved on nights when nurses were absent due to ND. Therefore, nurses and their spouses must sleep separately after ND to improve sleep quality.

Household chores were identified as an independent variable for RCSQ, but not sleep scores. RCSQ may more accurately reflect mental stress than the sleep score because RCSQ is based on subjective impressions (Gellerstedt et al., 2020), and the sleep score is simply calculated using objective data from a tracker (Lee et al., 2017). Mental stress from household chores may accumulate in the subconscious mind. On the other hand, since sleep scores are calculated from objective physical data, a difference was observed in sensitivity between RCSQ and sleep scores. In spouses, more factors were affecting sleep scores than RCSQ. Therefore, a sleep tracker, such as Fitbit, is sufficient for investigating sleep quality in further studies.

Strengths and Limitations

This study has four limitations that need to be addressed. The results obtained reflected conditions in urban districts. Since all participants lived around the local hospital, housing conditions may differ between an urban district and local area. Furthermore, none of the spouses had engaged in ND. Therefore, the interaction between nurses and their spouses due to ND was not investigated.

Moreover, the rate of use of sleep trackers is very low in Japan, and they are only routinely used by a small number of individuals. Therefore, the present study was designed with a short period and few participants. Long-term effects remain unknown. Additionally, the validity of Fitbit sleep data has yet to be validated in Japan.

Implications for Practice

This present study revealed specific changes in the sleep quality of nurses and their spouses with a sleep tracker. In the future, the sleep tracker may provide valuable data for improving the sleep quality of nurses and their spouses. Monitoring with sleep trackers might be helpful to keep nurses well on duty. The findings of this study recommend ensuring increased activity among nurses and their spouses for better sleep. In addition, the sleeping environment of couples after ND should be adjusted for the health of each other.

Conclusions

The sleep tracker may help identify factors that will improve sleep quality. The sleep quality in nurses and their spouses was affected using hypnotic medication, days on ND, and the number of steps. Therefore, proper hypnotic medications, separating bedrooms after ND, and good exercise could improve sleep quality in nurses and spouses. A large-scale study should be needed to improve the sleep quality of nurses and their spouses in the future.

Study Approval

Sapporo Medical University Ethics Committee: 4-1-19

ID number of clinical trial registration for UMIN: UMIN000048773

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Authors' Contributions

Tomohiro Ishinuki, Momoka Narumi Takeda, Erika Goda, Toshio Ohyanagi, Thomas T. Hui, and Toru Mizuguchi contributed to the conception and design of the present study, collected and analyzed data, and drafted the manuscript; Hiroomi Tatsumi, Hiroaki Shima, Hirofumi Ohnishi, and Yoshiki Masuda critically reviewed the manuscript and supervised the whole study process. All authors read and approved the final manuscript.

Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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