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Original article

Circadian Rhythms Characteristics of Nurses Providing Direct Patient Care: An Observational Study

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A B S T R A C T

Background: In today's modern world, longer working hours, shift work, and working at night have become major causes of the disruption of our natural circadian rhythms. This study aimed to investigate the effects of the type of shift work (rotating vs. fixed day), duty period (on-duty vs. off-duty), and working period within each shift (nighttime vs. daytime) on the circadian rhythm characteristics of nurses who provide direct patient care.
Methods: This cross-sectional study used a purposive sampling method. Cosinor analysis was applied to analyze the actigraphy data of nurses providing direct patient care for seven consecutive days. The linear mixed effects model was then used to determine any variances between shift type, duty period, and working period within each shift for the nurses.
Results: The mesor value did not differ according to nurses' shift type, duty period, and working period within each shift. The amplitude was statistically higher in on-duty nurses and in daytime working hours. The acrophase was significantly delayed in nighttime working hours. As well as nurses in rotating shift had experience.
Conclusion: Our findings revealed that the peak activity of nurses occurs significantly later at night while working and nurses working during nighttime hours may have a weaker or less distinct circadian rhythm. Thus, this study suggests that limits be placed on the number of rotating nighttime shifts for nurses.

1. Introduction

Circadian rhythms are defined as "physical, mental, and behavioral changes that follow a 24-hour cycle resulting from periodic changes between day and night [1]." Previous studies reported that circadian rhythm disturbances have a strong correlation with severe illnesses and health conditions, such as cardiometabolic disorders [1], depression [2], schizophrenia, bipolar disorder [3], hypertension, diabetes, cancer, obesity, and cardiovascular diseases [4,5]. Longer working hours, shift work, and working at night in today's world are among the main reasons for the alteration of circadian rhythms [4].

Health care services provided by hospitals must be fulfilled for 24 hours without interruption, which requires implementing a shift work system. Nurses working in hospitals generally follow a rotational schedule for 24 hour a day rather than a regular working routine [6,7]. They make up 19% of health care professionals working in Turkey, and the majority of them (95%) are employed by hospitals [8]. Previous studies have indicated that the shift system affects nurses' health physiologically, psychologically, and socially,

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including work-related musculoskeletal diseases [9], hormonal imbalance, cancer, sleep problems [10,11], fatigue [12], job dissatisfaction, burnout [13], psychiatric disorders, social isolation, loneliness, and deterioration in family relationships [14]. It also affects their circadian rhythms, resulting in an alteration of sleep/wake patterns and neurobehavioral dysfunction [15]. During the pandemic, many health care organizations had to reschedule their working hours. This change in work schedule, which was directly related to the pandemic, was closely associated with sleep disturbances.

During the pandemic, when this study was conducted, many health care organizations had to reschedule their working hours, and this change in work schedule related to the pandemic was closely associated with sleep disturbance [16]. Nurses who are working shifts and on the front lines of coronavirus disease 2019 (COVID-19) are especially prone to experiencing desynchronization of their circadian rhythm. This is due to long work hours with few breaks [17,18]. Furthermore, disruption of circadian rhythms has been linked to a decrease in both cellular and humoral immune response, potentially weakening nurses' ability to fight against COVID-19 symptoms [19]. Therefore, assessment of nurses' circadian activity rhythm (CAR) is important in terms of defining shift work-related health problems [20], providing treatment, and long-term management of these problems.

Circadian rhythm parameters of shift work nurses vary depending on shift type and shift length [15]. Previous studies using actigraphy have generally assessed the effect of shift work on nurses' sleep parameters [21,22]. The influence of shift work on nurses' CAR has been a research area in the last few decades [15,23]. Previous studies focusing on the influence of shiftwork on nurses' CAR include fixed 8-hour shift, including fixed day shifts (8 AM to 4 PM), evening shifts (4 PM to 12 AM), or night shifts (12 AM to 8 AM) [15], or rotational shiftwork including night shift and day shift [23]. The definition of "night shift" in Galasso et al's study, which was only conducted among orthopedic nurses, consisted of three consecutive working period, including fixed day shifts (7 AM to 2 PM), afternoon shifts (2 PM to 9 PM), night shifts (9 PM to 7 AM), and two consecutive resting period [23].

Rotating shift generally includes both day and night shifts over a 24-hour period [24]. The circadian rhythms characteristics of nurses practicing rotating shiftwork, particularly day-to-night work shifts, need to be a more precise determination [25,26] using an appropriate method that is considered time-varying covariates [27]. However, to the best of our knowledge, no study has evaluated the variations in circadian rhythms between day and night shift work, taking into account both fixed day and rotating shift types. Thus, this study aimed to investigate the effects of type of shift work (rotating vs. fixed day), duty period (on-duty vs. off-duty), and working period within each shift (nighttime vs. daytime) on the circadian rhythm characteristics of nurses who provide direct patient care.

2. Materials and methods

2.1. Design

This is a cross-sectional study in which the purposive sampling method was used. Participants were recruited from a private hospital in the Central Anatolia Region in Turkey between May 2020 and May 2021. Data were collected during the COVID-19 period. At that time, some private hospitals in Turkey were not designated as pandemic hospitals [28]. A private hospital was selected to conduct the study because there were no changes in nurses' working schedules during the COVID-19 pandemic. Inclusion criteria were as follows: providing direct patient care and having worked in the current clinic/unit for at least 6 months. Exclusion criteria were determined as follows: having a chronic disease, such as cardiovascular, neurological, psychiatric, etc.; being pregnant or in the postpartum period; having been diagnosed with sleep disorders; using hypnotic drugs affecting sleep; a body mass index value of <18.9 kg/m^2 or >29.9 kg/m^2; having a health problem such as upper extremity injury that would prevent using an actigraphy device; reluctance to give written consent. Ethical approval was obtained from the Ethics Committee of Bartın University (Protocol No: 2019-135). Institutional permission was obtained from the hospital where the research was conducted, and the research was carried out under the coordination of the director of nursing. All nurses were informed about the research, and then they provided consent to participate in the study.

2.2. Participants and procedures

The total number of nurses was 138 in the hospital, with over 120 hospital beds during the study period. Of these nurses, 36 who met the inclusion criteria and exclusion criteria were invited to participate in this study, and each participant gave their consent. The study data were collected by the second author using five actigraphy devices. Nurses were asked to wear the actigraphy device on their nondominant wrist for seven consecutive days [15,29] to keep it for 24 hours throughout the day and to continue normal daily activities. The data collection process was occasionally interrupted due to various reasons. For example, some nurses received a COVID-19 diagnosis and had to go on sick leave, which prevented us from obtaining actigraphy devices from them.

2.3. Measures

Data were collected using a questionnaire and an actigraphy device. Participants filled out the questionnaire on the first day when actigraphy devices were given to them. The questionnaire consisted of self-reported items about participants' age, gender, marital status, parental status, educational status [30], total work experience, total work experience in the current ward, shift type, and body mass index [31]. The *nurse shift schedule* of the participants in the hospital where the study was conducted was planned monthly, which included working 48 hours a week. The *shift type* was categorized as the *fixed day shifts* and *i rotating shifts*. The term "fixed day shift" was used to describe just working from 8 AM to 5 PM. All other work schedules, such as those from 8 PM to 8 AM or from 8 AM to 8 PM, were classified as "rotating shift" (Fig. 1).

2.3.1. Circadian rhythm

Actigraphy (ActiGraph GT3X-BT-Wrist actigraphy) was used to measure participants' circadian rhythms. This watch-like and validated device is worn by participants on the wrist of the nondominant arm to objectively monitor their sleep—wake cycle based on their movements [32]. In this study, participants started wearing an actigraphy device on their nondominant wrist on their first day of work and kept it on their wrist for seven consecutive days [15,29]. The sample data were recorded at 100 Hertz (100 samples per second) frequency and 15 (epochs) second intervals [33—35]. To transfer participant's activity count data to a computer file, ActiLife software (version 6.13.4) was used.

2.4. Statistical analysis

Frequencies, percentages, mean, and standard deviation values were used to report demographic data. Cole—Kripke algorithm was performed to calculate sleep efficacy by using actigraphy data [36]. The ratio of total time asleep to total time in bed is defined as sleep

Fixed day Shifts						
08.00-17.00	08.00-17.00	08.00-17.00	Off-duty	08.00-17.00	08.00-17.00	08.00-17.00
08.00-17.00	08.00-17.00	Off-duty	08.00-17.00	08.00-17.00	08.00-17.00	08.00-17.00
Rotating Shifts						
08.00-20.00	Off-duty	08.00-20.00	20.00-08.00	Off-duty	20.00-08.00	Off-duty
08.00-20.00	08.00-20.00	20.00-08.00	Off-duty	20.00-08.00	Off-duty	08.00-20.00
20.00-08.00	Off-duty	20.00-08.00	Off-duty	Off-duty	08.00-20.00	08.00-20.00

(1st Day) ⟷ (7th Day)

Fig. 1. Examples of shift schedules for fixed day shift and rotating shift nurses. The double pointed arrow points out duration of actigraphy monitoring.

efficiency [37]. A sleep efficiency of ≥85 is accepted as "normal" [38]. To compare sleep (≥85 sleep efficiency vs. <85 sleep efficiency) and cosinor parameter *t* test was performed. Cosinor analysis was preferred for the analysis of time series because it is simple, enables making reasonable predictions, and has wide areas of use [39]. This method uses the linear regression from the cycle period data for 24 hours, which are placed on the cosine curve to obtain mesor, amplitude, and acrophase parameters. Mesor is a rhythm-adjusted mean that serves as a measure of the central tendency of the circadian rhythmic pattern. Amplitude means the measure of how far the data points deviate from the mesor to reach the peak of the oscillation. A larger amplitude indicates a more pronounced or stronger rhythmic pattern, whereas a smaller amplitude suggests a weaker or less pronounced rhythm. Acrophase is the time at which the peak or maximum amplitude of the oscillation occurs within one cycle. These parameters help in quantifying and understanding the characteristics of rhythmic patterns in circadian rhythms [39–41].

In this study, raw data of 25 participants who wore the actigraphy device for 24 hours for seven consecutive days were included in the analysis. The activity count (raw data), fitted to the cosine curve at equal intervals of 24 hours via cosinor analysis, and circadian parameters (mesor, amplitude, and acrophase) were obtained separately for each of seven consecutive days. Circadian parameters were calculated using 10.080 raw data obtained from 25 participants for seven consecutive days. Although there is no current consensus on the best handling procedure regarding missing data in actigraphy, the exclusion of a whole day when missing time exceeds a certain length on that day or the substitution of missing data by the addition of new data such as mean and median of weekly time points are recommended [42]. In this study, the data of 11 participants were omitted because of missing time exceeding over 4 hours a day [43]. R software (version 4.1.1, https://cran.r-project.org/bin/windows/base/old/4.1.1/) with metapackage (version 5.1-1) was used for data analysis. The categorical variables in this study were defined as three groups: (1) fixed day shift versus rotating shift (*shift type*); (2) on-duty versus off-duty (*duty period*); and (3) nighttime working versus daytime working (*working period within each shift*). To define the working period, working hours in shifts separated into two categories, which are nighttime working (5 PM to 8 AM) and daytime working (8 AM to 5 PM). In this study, covariates, shift type, duty period, and working period within each shift were controlled for and entered into the model as fixed effects [44]. Day was considered as a repeated effect. To manage time-varying factors related to rotating shifts, this study used a linear mixed effects model [27].

3. Results

Demographic characteristics of nurses are presented in Table 1. The mean age of the participants was 25.88 (standard deviation, 5.40), and the majority of them (80%) were female. More than two-thirds of the participants (68%) were single, 72% had no children, 68% had a high school education, and more than half (60%) had normal weight. Only 12% of participants had less than 1 year of work experience, and more than three-fourths (76%) had been

Table 1
Participants' sociodemographic characteristics

Variables	*n*	%
Age (standard deviation; minimum to maximum)	25.88 (5.40; 21–42)	
Gender		
Female	20	80
Male	5	20
Marital status		
Single	17	68
Married	8	32
Parental status		
None	18	72
One child	6	24
Two children	1	4
Educational status*		
High school levels	17	68
Associate degree programs	3	12
Colleges of nursing	5	20
Body mass index		
Normal weight (18.5–24.9)	15	60
Overweight (25.0–29.9)	10	40
Duration of working life		
<1 year	3	12
1–4 year(s)	8	32
5–10 years	11	44
>10 years	3	12
Duration of working time in the current ward		
<1 year	6	24
1–4 year(s)	11	44
5–10 years	6	24
>10 years	2	8
Shift type		
Rotating shift (8 AM to 8 PM or 8 PM to 8 AM)	15	60
Fixed day shift (8 AM to 5 PM)	10	40

* Bahçecik and Alpar, 2009.

Table 2
Cosinor parameters according to shift type, duty period, and working period within each shift

Variables	Mean	Standard deviation	Median	Minimum	Maximum
Mesor (total)	133.78	69.14	140.85	−166.98	257.61
Rotating shift	132.27	72.46	146.67	−128.24	242.68
Fixed day shift	136.06	64.28	139.57	−166.98	257.61
On-duty	135.30	70.88	146.61	−166.98	257.61
Off-duty	129.41	64.40	124.94	0.66	235.75
Nighttime working[*]	136.64	66.38	149.82	0.90	224.71
Daytime working[*]	134.79	72.87	141.13	−166.98	257.61
Amplitude	133.80	77.01	131.47	0.15	539.65
Rotating shift	134.11	86.68	131.16	1.38	539.65
Fixed day shift	133.33	60.24	132.89	0.15	400.10
On-duty	145.55	79.60	137.91	0.15	539.65
Off-duty	99.85	57.32	96.51	1.31	227.45
Nighttime working[*]	126.51	60.66	131.07	1.38	216.28
Daytime working[*]	152.84	84.92	139.28	0.15	539.65
Acrophase (h:min)	0:23	0:96	0:49	1:57	1:57
Rotating shift	0:19	1:06	0:51	1:55	1:57
Fixed day shift	0:29	0:79	0:42	1:57	1:57
On-duty	0:10	0:96	0:39	1:56	1:57
Off-duty	0:60	0:88	0:70	1:57	1:57
Nighttime working[*]	0:52	1:11	0:64	0:21	1:52
Daytime working[*]	0:21	0:87	0:41	0:03	1:57

(1) Fixed day shift versus rotating shift (shift type); (2) on-duty versus off-duty (duty period); and (3) nighttime working versus daytime working (working period within each shift).
[*] The sum samples of nighttime working and daytime working was equal sample of on-duty (fixed day shift + rotating shift).

working in their current ward for more than 1 year. The percentage of nurses working rotating shifts was 60%.

Mean, standard deviation, median, and minimum-maximum values of cosinor parameters according to shift type, duty period, and working period within each shift are illustrated in Table 2. The rhythm-adjusted mean (MESOR) value was 132.27 (standard deviation, 72.46) in the total sample, with the highest value being 136.64 (standard deviation, 66.38) in nighttime working hours. The mean of AMPLITUDE was calculated as 133.80 (standard deviation, 77.01) in the total sample, with the highest mean value being 152.84 (standard deviation, 84.92) in daytime working hours. The mean of ACROPHASE was 0.23 (standard deviation, 0.96) in the total sample, with the lowest value being 0.10 (standard deviation, 0.96) in on-duty nurses.

The main effects of shift type, duty period, and working period within each shift revealed by using a linear mixed model with repeated measures are presented in Table 3. The rhythm-adjusted mean did not differ according to nurses' shift type (coefficient = −12.08; p = 0.391), nighttime working (coefficient = 7.70; $p = 0.588$), daytime working (coefficient = 11.21; $p = 0.339$), and on-duty (coefficient = 11.47; $p = 0.284$) in Model 1. However, the amplitude was statistically higher in on-duty nurses (coefficient = 51.93; $p < 0.001$) and in daytime working hours (coefficient = 37.22; $p = 0.013$). Moreover, the acrophase was significantly different on-duty and off-duty periods (coefficient = −0.51; $p < 0.001$). The acrophase was significantly delayed in nighttime working hours ($t = -0.80$; $p < 0.001$) compared with daytime working

Table 3
The main effects of shift type, duty period, and working period within each shift using a linear mixed model with repeated measures

Parameters	Model 1							Model 2						
	Estimate	Standard. error	df	t	Sig.	95% Confidence interval		Estimate	Standard error	df	t	Sig.	95% Confidence interval	
						Lower bound	Upper bound						Lower bound	Upper bound
Mesor														
Shift type (rotating)[*]	−12.08	13.82	23.00	−0.87	0.391	−40.67	16.51	−3.06	20.34	13.10	−0.15	0.883	−46.98	40.86
Nighttime working[†]	7.70	12.45	2.51	0.62	0.588	−36.70	52.09	7.62	13.30	3.85	0.57	0.599	−29.88	45.12
Daytime working[†]	11.21	10.99	7.49	1.02	0.339	−14.43	36.85	9.79	11.43	9.36	0.86	0.413	−15.91	35.50
Duty period (on-duty)[‡]	11.47	10.61	56.44	1.08	0.284	−9.78	32.72							
Amplitude														
Shift type (rotating)[*]	−1.51	23.39	129.66	−0.06	0.949	−47.79	44.76	5.13	21.34	81.12	0.24	0.811	−37.32	47.59
Nighttime working[†]	24.77	16.26	83.95	1.52	0.131	−7.56	57.11	24.97	14.78	13.67	1.69	0.114	−6.80	56.74
Daytime working[†]	37.22	13.92	24.61	2.67	0.013	8.52	65.93	37.44	12.47	16.20	3.00	0.008	11.02	63.86
Duty period (on-duty)[‡]	51.93	9.00	17.84	5.77	0.000	33.01	70.86							
Acrophase														
Shift type (rotating)[*]	−0.07	0.18	0.87	−0.41	0.761	−3.28	3.14	0.02	0.26	10.34	0.06	0.952	−0.55	0.58
Nighttime working[†]	−0.80	0.19	131.32	−4.24	0.000	−1.18	−0.43	−0.87	0.20	17.99	−4.36	0.000	−1.29	−0.45
Daytime working[†]	−0.40	0.17	166.04	−2.33	0.021	−0.74	−0.06	−0.49	0.17	24.08	−2.82	0.009	−0.85	−0.13
Duty period (on-duty)[‡]	−0.51	0.12	64.20	−4.15	0.000	−0.76	−0.27							

Model 1: Shift type, duty period, and working period within each shift entered the model as fixed effects. Day was considered as repeated effect.
Model 2: Shift type, duty period, and working period within each shift entered the model as fixed effects. Shift type + duty period was random effect. Day was considered as repeated effect. Mesor, amplitude, and acrophase parameters were calculated using 10.080 raw data obtained from seven consecutive days of 25 participants. The sum samples of nighttime working and daytime working was equal sample of on-duty (fixed day shift + rotating shift).
(1) Fixed day shift versus rotating shift (shift type); (2) on-duty versus off-duty (duty period); and (3) nighttime working versus daytime working (working period within each shift).
[*] Shift type was random effect.
[†] Duty period was random effect.
[‡] Working period within each shift was random effect.

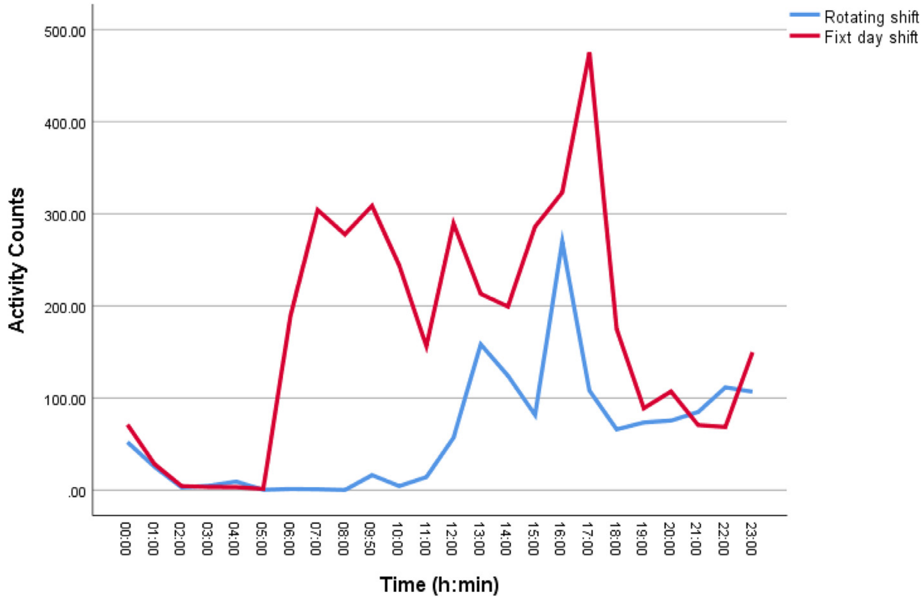

Fig. 2. Circadian rhythms in nurses who work fixed day shifts or rotating shifts during their working days.

hours (coefficient = −0.40; $p = 0{,}021$; Table 3; Figs. 2 and 3), with about 30 minutes (Table 2).

Model 2 showed that mesor did not differ according to nurses' shift type, duty period, and working period within each shift ($p > 0.05$). Amplitude was statistically the highest in daytime working hours (coefficient = 37.44; $p = 0.008$). Moreover, acrophase was delayed in nighttime working hours (coefficient = −0.87; $p < 0.001$) compared with daytime working hours (coefficient = −0.49; $p = 0.009$; Table 3; Figs. 2 and 3).

4. Discussion

Previous studies focusing on the influence of shift work on nurses' CAR include fixed 8-hour shift [15] or rotational shiftwork on circadian rhythms in a specific nursing ward [23]. This study determined the effect of shift work including fixed day shift and rotating shift on circadian rhythms characteristics of nurses providing direct patient care. Furthermore, the study assessed duty period (on-duty vs. off-duty) and working period within each shift (nighttime vs. daytime) on circadian rhythms.

Our results indicated that mesor did not differ according to nurses' shift type (fixed day vs. rotating shift), duty period (on-duty vs. off-duty), and working period (nighttime vs. day time). A previous study on the influence of fixed 8-hour shifts for at least 1 month on the circadian rhythms of nurses showed that mesor did not differ between the day shift and night shift [15], which was consistent with our study findings. A previous study reported that nurses working on fixed day shift performed more activity level

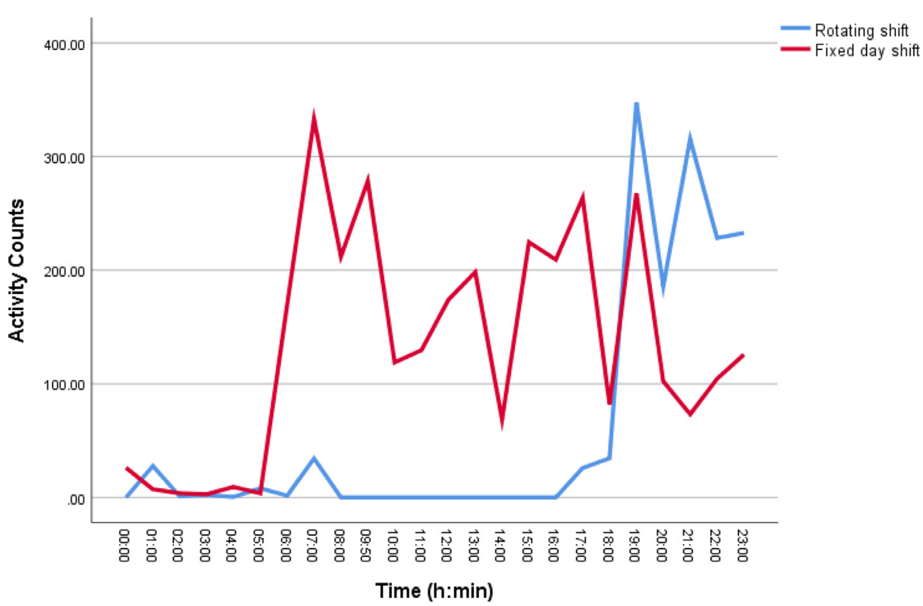

Fig. 3. Circadian rhythms in nurses who work fixed day shifts or rotating shifts during their rest days.

than those working in rotating shift because of low mesor [23], which means reduced activity and rhythmicity [45,46]. In this present study, although the difference was not statistically significant, the mesor was slightly lower in rotating shifts compared with fixed day shifts. In addition, it was also lower during daytime working hours compared with nighttime working hours. Thus, it can be argued that nurses who work rotating shifts tend to be less active compared with those who work fixed day shift. Additionally, nurses who work during daytime, regardless of whether they work rotating or fixed day shifts, experience less activity compared with those who work during nighttime hours.

We found that the acrophase was significantly delayed in nighttime working hours, with about 30 minutes. A previous study had similar results in terms of delayed acrophase between daytime and nighttime working periods [23]. In addition, the study revealed that nurses on duty experienced a significantly smaller delay in acrophase. The result regarding on-duty versus off-duty is consistent with a previous study [15]. The variations in acrophase may not always accompanied by a difference in mesor [47], and the instability of the sleep−wake cycle of nurses working in rotating shift might have affected their circadian rhythms [15]. The circadian rhythms of nurses might not be altered by scheduling just one night shift each week [23]. On a 7-day shift plan, most nurses working rotating shifts in our study worked at least three nights. In addition, this study did not find any statistical differences between rotating shifts and fixed day shifts. Thus, it was evident that the peak activity of nurses occurs significantly later at night while working compared with the typical 24-hour pattern. A delayed acrophase can have clinical significance. It may be associated with symptoms or health issues, particularly when the normal synchronization of circadian rhythms is disrupted.

Although there were not any differences between fixed day and rotating shift nurses, the amplitude was statistically higher among nurses who were on duty. In addition, nurses working during the day, regardless of whether they are on a rotating or fixed shift, had higher amplitude compared with those working at night. While some previous studies reported lower amplitude in rotating shift nurses compared with morning shift nurses [23,48], there is also evidence to state higher amplitude in day shift nurses compared with those working night or evening shifts [15]. However, there is consistent evidence that amplitude is higher during the on-duty period than the rest period [15,23,48]. The variations in amplitude may not always correspond to variations in mesor; thus, it appears to control circadian variation is necessary to assess circadian rhythm changes [47]. Nurses' increased activity levels during daytime working hours might be caused by their high workload throughout this period [49]. Our study also showed that nurses were more active during daytime working hours than nighttime working hours, regardless of whether they work rotating or fixed day shifts. It is already known that shift work with night shifts was associated with increased fatigue compared with shift work without night shifts [50]. Thus, when work schedules are planned for nurses, it is important to consider that night shift nurses have inconsistent working routines contrary to day shift nurses [48]. Based on the results of this study and evidence from previous studies, it can be suggested that nurses who work during nighttime hours may have a weaker or less distinct circadian rhythm. This places them at a heightened risk of encountering negative health conditions, developing diseases, committing medical errors, and ultimately contributing to adverse patient safety issues [51,52]. Implementing appropriate interventions is crucial to minimize the impact of nighttime work on nurses' health, prevent the misalignment between their sleep−wake rhythm and its negative effects [53], and enhance well-being among nurses, thereby increasing patient safety [54,55].

The present study has several limitations. First, the study was limited to one private hospital and had a small sample size with a young age range; therefore, the findings could not be generalized. Second, we did not consider resting time activities as an off-duty period, which might have affected the results. Finally, the relevant environmental factors that ought to be recommended for consideration in future studies, such as light exposure, were not measured in the present study.

This study can be argued that nurses who work rotating shifts tend to be less active compared with those who work fixed day shift as well as nurses who work during daytime, regardless of whether they work rotating or fixed day shifts, experience less activity compared with those who work during nighttime hours. In addition, it was evident that the peak activity of nurses occurs significantly later at night while working compared with the typical 24-hour pattern. Thus, nurses working during the nighttime may be at a higher risk for experiencing symptoms or health issues because their normal circadian rhythms are disrupted. In addition to causing negative health conditions, a disturbed circadian rhythm among nurses working night shifts is closely correlated with an increased risk of medical errors and a higher rate of adverse patient safety issues.

Future studies should be conducted using larger and more representative samples of different shift types over a longer period to further understand changes in nurses' circadian rhythms, considering the effects of confounding factors such as light exposure and factors reducing the effects on nurses' circadian rhythms. In light of the study, nurses who frequently work during nighttime hours should be periodically assessed for potential risks of developing diseases and experiencing negative health conditions. This study suggests that imposing limits on the number of rotating nighttime shifts for nurses is crucial to protect both patients from adverse events and nurses from the negative health conditions caused by disturbed circadian rhythm. Accordingly, improvements in nurses' health conditions, achieved through the development of supporting programs and the implementation of evidence-based scheduling strategies, may lead to better nursing care for patients.

Data accessibility statement

The data sets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Author's contribution

İ.D. contributed to conceptualization; methodology; validation; resources; writing, reviewing, and editing; visualization; supervision; project administration; and funding acquisition. S.A. contributed to conceptualization, investigation, data curation, and reviewing and editing. A.R.D. contributed to reviewing and editing. E.K. contributed to Formal analysis.

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Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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