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Cumulative night-shift burden and sleep quality among healthcare Workers: Dose–response evidence from an analytical cross-sectional study

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Abstract

Background

Shift work is common among healthcare workers; however, the effects of cumulative night-shift exposure on sleep dimensions and the pathways linking shift work with sleep quality remain insufficiently understood. This study examined the association between shift-work characteristics and sleep quality, emphasizing cumulative night-shift burden.

Methods

An analytical cross-sectional study was conducted among 411 healthcare workers selected using a two-stage sampling strategy. Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), and poor sleep quality was defined as a global PSQI score > 5. Multivariable logistic regression identified predictors of poor sleep quality. Dose-response relationships between monthly night-shift frequency and poor sleep quality were evaluated using quartile analyses and restricted cubic spline modelling. Individual PSQI component scores identified sleep domains most affected by shift work, and exploratory path analysis investigated pathways linking shift-work exposure with sleep quality.

Results

Poor sleep quality was prevalent. Cumulative night-shift exposure emerged as the strongest predictor of poor sleep quality. Increasing monthly night-shift frequency demonstrated a dose-response relationship, with higher odds of poor sleep quality. Night-shift burden was associated with shorter sleep duration, poorer sleep efficiency, increased sleep disturbances, and daytime dysfunction. Exploratory path analysis supported a pathway in which cumulative night-shift exposure was associated with prolonged sleep latency.

Conclusions

Cumulative night-shift burden is an occupational determinant of poor sleep quality. These findings demonstrate dose-dependent effects of night-shift exposure and identify sleep domains most affected. Reducing night-shift exposure and incorporating sleep health into occupational health programmers may improve well-being, workforce sustainability, and patient safety.

1. Background

Healthcare systems rely on continuous and around the clock service delivery, requiring many healthcare workers to perform evening, night, and rotating shifts to ensure continual patient care. Although these work schedules are essential for keeping healthcare services, they expose workers to unusual working

hours that challenge normal sleep patterns and recovery. Adequate sleep is fundamental for maintaining physical health, cognitive performance, emotional well-being, and occupational functioning [1, 2]. Conversely, insufficient or poor-quality sleep has been associated with impaired attention, slower reaction times, reduced clinical decision-making [3] increased occupational injuries, and a greater risk of medical errors with important consequences for healthcare workers and patient safety [4, 5]. As shift work has become a component of healthcare systems worldwide, understanding the occupational factors that contribute to sleep disturbances has become a priority for occupational health research and workplace health promotion.

Night-shift work disrupts normal sleep by altering the synchronization between the endogenous circadian timing system and externally imposed work schedules [6]. Under normal conditions, the circadian rhythm coordinates the timing of sleep and wakefulness, while sleep homeostasis regulates the accumulation and dissipation of sleep pressure to maintain restorative sleep [7]. Working during the biological night and attempting to sleep during the daytime creates circadian misalignment, in which behavioral sleep–wake schedules become out of phase with internal biological rhythms [8]. Because complete physiological adaptation to rotating or irregular night shifts is uncommon, repeated circadian misalignment reduces sleep opportunity, impairs sleep quality, and limits recovery between successive work shifts [9]. Consequently, healthcare workers engaged in night and rotating shift schedules consistently report poorer sleep quality than their counterparts working regular daytime schedules [10].

Epidemiological evidence indicates that shift work is consistently associated with impaired sleep among healthcare workers. Recent systematic reviews and meta-analyses have shown that night and rotating shift workers experience poorer subjective sleep quality, shorter sleep duration, greater insomnia symptoms, and increased daytime sleepiness than permanent day workers [9, 11]. These adverse sleep outcomes have been reported across diverse healthcare professions, including nurses, physicians, and allied health personnel, suggesting that sleep impairment is a common occupational consequence of non-standard work schedules rather than being confined to a particular professional group [12]. However, most epidemiological studies have focused primarily on comparing shift workers with non-shift workers or examining overall sleep quality, with limited attention to the cumulative burden of night-shift exposure, potential dose response relationships or the specific dimensions of sleep most affected by shift work [13, 14].

studies have classified participants simply as shift workers or non-shift workers or compared broad work schedules with relatively few quantifying cumulative night-shift burden as an occupational exposure [15]. Consequently, evidence regarding whether increasing night-shift exposure progressively worsens sleep quality remains limited. In addition, although the Pittsburgh Sleep Quality Index (PSQI) is widely used, most studies have focused on the global score rather than individual sleep domains providing limited insight into which dimensions of sleep are most vulnerable to night work. Furthermore, few studies have combined complementary analytical approaches to investigate dose response relationships and explore potential pathways linking shift work exposure with sleep quality. Therefore, questions remain regarding whether increasing exposure to night shifts worsens sleep quality, which

specific sleep domains are most vulnerable, and the pathways through which cumulative night shift burden influences sleep health. Addressing these questions is essential for identifying modifiable occupational risk factors and informing evidence-based interventions to improve sleep health among healthcare workers.

In response to these knowledge gaps, this analytical cross-sectional study examined the association between shift work characteristics and sleep quality among healthcare workers. Specifically, the study aimed to identify the independent occupational predictors of poor sleep quality, evaluate whether cumulative night-shift exposure demonstrates a dose response relationship with sleep impairment, determine which dimensions of sleep are most affected by night-shift work, and explore potential pathways linking shift-work exposure with overall sleep quality. We hypothesized that greater cumulative night-shift exposure would be independently associated with poorer sleep quality, that increasing night shift frequency would demonstrate a graded dose response relationship with sleep impairment, and that disruption of sleep initiation would be consistent with a pathway linking night shift burden with overall sleep quality.

2. Methods

2.1 Study Design and Setting

This analytical cross-sectional study was conducted among healthcare workers employed in teaching hospitals affiliated to Medical Sciences University in Semnan. The study examined the association between shift work characteristics and sleep quality, with emphasis on the role of night shift exposure. Data were collected between September 2024 and March 2025 using a structured self-administered questionnaire.

2.2 Study Population and Sampling

Eligible participants included physicians, nurses, allied health professionals, and support staff who were actively employed at participating healthcare facilities during the study period. Inclusion criteria comprised employment for at least six months and direct involvement in healthcare service delivery. Individuals with incomplete questionnaire data were excluded from the final analyses. The minimum required sample size was estimated using the single population proportion formula with finite population correction, assuming a 95% confidence level ($Z = 1.96$), a margin of error of 5%, an expected proportion of 50% (to maximize sample size in the absence of prior estimates), and an anticipated nonresponse rate of 10%. The minimum required sample size was calculated to be 273 participants.

A two-stage probability sampling strategy was used to ensure representative sampling across hospital departments. In the first stage, proportionate stratified sampling was used to assign the required number of participants to each clinical and non-clinical unit according to the number of healthcare workers employed in that unit. In the second stage, eligible participants within each unit were selected using simple random sampling until the predetermined sample size for each stratum was achieved.

Participants with missing information on variables required for specific analyses were excluded only from those analyses while all available observations were retained for descriptive analyses.

2.3 Data collection and variables

Data were collected using a structured questionnaire consisting of demographic, occupational, work-schedule, and sleep related sections.

2.3.1 Sociodemographic and occupational variables

Information was obtained regarding age, sex, marital status, educational level, and occupation. Occupational information included professional role, service category, shift schedule, shift duration, number of night shifts worked per month, and monthly overtime hours. To improve statistical stability and facilitate multivariable analyses, occupational roles were grouped into broader occupational categories and hospital wards were collapsed into service categories based on clinical similarity and sample size considerations.

2.3.2 Sleep quality assessment

Sleep quality was assessed using the previously published Persian version of the Pittsburgh Sleep Quality Index (PSQI), which evaluates subjective sleep quality over the preceding month [16]. The PSQI comprises seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component is scored from 0 to 3, and the component scores are summed to yield a global score ranging from 0 to 21, with higher scores indicating poorer sleep quality. A global PSQI score of ≥ 6 was considered indicative of poor sleep quality. The Persian version of the PSQI has demonstrated acceptable psychometric properties among Iranian hospital personnel, including physicians and nurses, with a Cronbach's α of 0.55 and a significant correlation with the General Health Questionnaire-28 ($r = 0.479$, $P < 0.01$); exploratory factor analysis identified three factors explaining 63.485% of the total variance [17].

2.4 Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version SPPS version 26.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was defined as a two-sided p-value < 0.05.

2.4.1 Descriptive analysis

Participant characteristics and sleep quality indicators were summarized using means and standard deviations for continuous variables and frequencies and percentages for categorical variables.

2.4.2 Comparison of sleep quality across occupational and work schedule characteristics

Differences in PSQI scores across occupational and work-schedule categories were evaluated using one-way analysis of variance (ANOVA) or Kruskal–Wallis tests as appropriate. Associations between categorical variables and poor sleep quality were examined using chi-square tests. Effect sizes were reported using eta-squared (η^2) for continuous outcomes and Cramer's V for categorical comparisons.

2.4.3 Logistic regressions

Univariate logistic regression analyses were performed to estimate crude associations between demographic, occupational, and work-schedule variables and poor sleep quality (PSQI > 5). Crude odds ratios (ORs), 95% confidence intervals (CIs), and p-values were reported. Multivariable logistic regression analysis was performed to identify demographic, occupational, and work-schedule factors independently associated with poor sleep quality among healthcare workers. Variables of epidemiological relevance and those associated with poor sleep quality in univariate analyses were entered into a multivariable logistic regression model. Adjusted odds ratios (AORs) with 95% confidence intervals were calculated to identify independent predictors of poor sleep quality. We assessed model discrimination using the area under the receiver operating characteristic Area Under the Curve (AUC) (AUC) and calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Model explanatory power was assessed using Nagelkerke's R^2 statistic. Multicollinearity was examined using variance inflation factors (VIFs).

2.4.4 Dose–Response Analysis

We examined whether increasing night-shift burden was associated with progressively higher odds of sleep impairment, participants were categorized into quartiles according to the number of night shifts worked per month. Multivariable logistic regression analyses were repeated using the lowest exposure quartile (Q1) as the reference category while adjusting for the same covariates included in the primary model. Also restricted cubic spline regression was used to evaluate the shape of the association between continuous night-shift exposure and the predicted probability of poor sleep quality.

2.4.5 Analysis of individual sleep domains

To determine which dimensions of sleep were most strongly affected by shift-work exposure, separate multivariable regression analyses were performed for individual PSQI component scores. Sleep latency, sleep duration, sleep efficiency, sleep disturbances, and daytime dysfunction were examined as dependent variables, while shift schedule, night-shift frequency, and overtime work were included as predictors. All models were adjusted for age and sex.

2.4.6 Exploratory path analysis

An exploratory path analysis was performed to investigate potential mechanisms linking shift-work characteristics and sleep quality. Based on circadian-disruption theory, a conceptual pathway was specified in which shift schedule influenced sleep quality through increased night-shift exposure and subsequent effects on sleep latency. Standardized path coefficients were estimated to evaluate direct and indirect associations between variables. Because of the cross-sectional design, the path analysis was considered exploratory and hypothesis generating rather than confirmatory.

3. Results

3.1 Participant characteristics

A total of 411 healthcare workers were included in the analysis. Participant characteristics according to demographic, occupational, and work-schedule variables are presented in Table 1. The mean age of participants was 32.3 years (SD = 8.4 years), with the largest proportion aged 26–35 years (45.5%). Women constituted approximately two-thirds of the study population (69.8%).

Table 1. Sociodemographic and occupational characteristics of healthcare workers (N = 411)

Categorized variables	n	%
Sex		
Female	287	69.8
Male	124	30.2
Age group (years)		
≤25	107	26.0
26–35	187	45.5
36–40	46	11.2
≥41	71	17.3
Educational status		
Graduate	214	52.1
Student	197	47.9
Educational level		
Non-university	28	6.8
Bachelor's degree	95	23.1
Graduate/Professional degree	288	70.1
Occupational group		
Physicians	263	64.0
Nursing and allied clinical staff	96	23.4
Support services	52	12.7
Hospital service category		
General wards	233	56.7
Acute/critical care services	80	19.5
Specialized care services	14	3.4
Non-clinical services	84	20.4
Shift schedule		
Fixed day shift	70	17.0
On-call shift	74	18.0
Rotating shift	267	65.0

Categorized variables	n	%
Continuous variables	**Mean**	**± SD**
Age (years)	32.28	± 8.44
Shift duration (hours)	18.17	± 8.88
Shifts per month	14.75	± 9.47
Night shifts per month	7.24	± 5.03
Overtime hours per month	24.15	± 39.23

3.2 Sleep quality profile of participants

Poor sleep quality was highly prevalent among healthcare workers, with the majority of participants classified as having poor sleep quality (global PSQI score >5). The mean (± SD) global PSQI score was 7.49 (SD = 3.05) indicating generally impaired sleep quality across the study population. Among the PSQI domains, the greatest impairments were observed in sleep duration, sleep disturbances, and daytime dysfunction. Detailed distributions of the global PSQI score and individual component scores are presented in Table 2.

Table 2. Sleep quality of healthcare workers (N = 411)

Variable	Mean ± SD	Median (IQR)	Range
PSQI global score	7.49 ± 3.05	7 (5–9)	1–16
Subjective sleep quality	1.17 ± 0.78	1 (1–2)	0–3
Sleep latency	1.64 ± 1.06	2 (1–2)	0–3
Sleep duration	0.96 ± 0.93	1 (0–2)	0–3
Habitual sleep efficiency	0.76 ± 1.03	0 (0–2)	0–3
Sleep disturbances	1.39 ± 0.59	1 (1–2)	0–3
Sleep medication use	0.22 ± 0.67	0 (0–0)	0–3
Daytime dysfunction	1.34 ± 0.85	1 (1–2)	0–3
Sleep quality category	**N**	**% (95% CI)**	
Good sleep quality (PSQI ≤5)	145	35.3% (30.7–40.0)	
Poor sleep quality (PSQI >5)	266	64.7% (60.0–69.3)	

Abbreviations: PSQI, Pittsburgh Sleep Quality Index; SD, standard deviation; IQR, interquartile range.

3.3 Sleep quality according to occupational and work-schedule characteristics

Sleep quality varied across occupational and work-schedule characteristics (Table 3). Healthcare workers engaged in rotating or night-shift schedules reported poorer sleep quality than those working regular daytime schedules. Poorer sleep quality was observed among participants with longer shift durations, more frequent monthly night shifts, and greater overtime workloads. In contrast, differences according to demographic characteristics were relatively small. Variations in sleep quality were also observed across occupational groups and clinical service categories but these differences were less noticeable than those related to work-schedule characteristics. Overall, poorer sleep quality was more consistently observed among participants with greater exposure to demanding work schedules. Detailed comparisons across participant subgroups are presented in Table 3.

Table 3. Differences in PSQI global scores according to occupational and work-schedule characteristics (N = 411)

Characteristic	n	Mean PSQI ± SD	p-value	η^2
Occupational group			0.112	0.011
Physicians	263	8.57 ± 3.77		
Nursing and allied clinical staff	96	7.67 ± 3.53		
Support services	52	8.46 ± 3.28		
Hospital service category			0.028	0.022
General wards	233	7.97 ± 3.63		
Acute and critical care services	80	8.68 ± 3.78		
Specialized care services	14	7.36 ± 3.69		
Non-clinical services	84	9.24 ± 3.51		
Shift schedule			0.571	0.003
Fixed day shift	70	7.93 ± 3.67		
On-call shift	74	8.38 ± 3.44		
Rotational shift	267	8.45 ± 3.73		

PSQI = Pittsburgh Sleep Quality Index. P-values were obtained using one-way analysis of variance (ANOVA). Eta-squared (η^2) was used to estimate effect size, with values of approximately 0.01, 0.06, and 0.14 representing small, medium, and large effects, respectively.

3.4 Unadjusted associations between shift work characteristics and poor sleep quality

Univariate logistic regression analyses identified several work-schedule characteristics that were associated with impaired sleep quality (Table 4). Monthly night-shift frequency, shift schedule, longer shift duration and increased overtime workload showed evidence of association with poor sleep quality in the unadjusted analyses. Associations were observed for selected occupational characteristics, whereas demographic variables demonstrated little evidence of association. Complete unadjusted odds ratios and corresponding confidence intervals are presented in Table 4.

Table 4. Univariate logistic regression analysis of factors associated with poor sleep quality among healthcare workers (N = 411)

Predictor	Category / Unit	Crude OR	95% CI	p-value
Sex	Male vs Female	1.37	0.89–2.12	0.150
Age	Per 1-year increase	1.05	1.02–1.08	<0.001
Occupational group[1]	Physicians' vs Nursing/allied clinical staff	0.57	0.35–0.93	0.025
	Support services vs Nursing/allied clinical staff	0.39	0.19–0.78	0.008
Hospital service category[2]	General wards vs Acute/critical care	0.60	0.35–1.02	0.059
	Non-clinical services vs Acute/critical care	0.56	0.29–1.05	0.069
	Specialized care vs Acute/critical care	0.64	0.20–2.04	0.453
Shift schedule[3]	On-call vs Fixed day shift	2.62	1.25–5.50	0.011
	Rotational vs Fixed day shift	0.68	0.40–1.16	0.161
Shift duration	Per 1-hour increase	0.98	0.95–1.00	0.033
Night shifts/month	Per additional night shift	1.07	1.03–1.12	<0.001
Overtime/month	Per additional overtime hour	1.00	1.00–1.01	0.124

Outcome: Poor sleep quality (PSQI >5),[1] Reference group: Nursing and allied clinical staff.[2] Reference group: Acute and critical care services.;[3] Reference group: Fixed day shift.

3.5 Independent predictors of poor sleep quality

The multivariable logistic regression model identified work-schedule characteristics as the principal determinants of poor sleep quality (Table 5). Monthly night-shift frequency emerged as the strongest predictor, while longer shift duration and greater overtime workload also remained associated with sleep impairment. Demographic characteristics and several occupational variables were no longer associated with poor sleep quality after adjustment for potential confounders. The final model demonstrated satisfactory overall performance with acceptable calibration and discrimination. Detailed adjusted odds ratios, 95% confidence intervals, and model performance statistics are presented in Table 5.

Table 5. Multivariable logistic regression model for poor sleep quality among healthcare workers (N = 411)

Predictor	Adjusted OR (AOR)	95% CI	p-value
Sex			
Male vs Female	1.42	0.86–2.35	0.171
Age			
Per 1-year increase	1.02	0.98–1.06	0.324
Occupational group*			
Nursing and allied clinical staff vs Physicians	0.71	0.40–1.26	0.241
Support services vs Physicians	0.83	0.38–1.82	0.645
Service category†			
Acute/critical care vs General wards	1.28	0.72–2.28	0.398
Specialized care vs General wards	0.81	0.24–2.73	0.735
Non-clinical services vs General wards	1.37	0.74–2.54	0.315
Shift schedule‡			
On-call vs Fixed day shift	2.94	1.16–7.43	0.023
Rotational vs Fixed day shift	1.69	0.83–3.44	0.149
Shift duration			
Per additional hour worked	1.03	1.00–1.07	0.041
Night shifts/month			
Per additional night shift	1.11	1.04–1.18	0.001
Overtime/month			
Per additional overtime hour	1.00	0.99–1.01	0.582

Model Performance

Statistic	Value
Sample size analyzed	399
Nagelkerke R^2	0.182
Hosmer–Lemeshow goodness-of-fit test (p-value)	0.318
Area under ROC curve (AUC)	0.736

AOR, adjusted odds ratio; CI, confidence interval; ROC, receiver operating characteristic; AUC, area under the curve.

* Reference group = Physicians. † Reference group = General wards.

‡ Reference group = Fixed day shift.

3.6 Dose response relationship between night shift exposure and poor sleep quality

Table 6 shows a dose response analysis by categorizing participants into quartiles according to the number of night shifts worked per month. A progressive increase in the adjusted odds of poor sleep quality was observed across successive exposure quartiles with participants in the highest quartile demonstrating the greatest likelihood of poor sleep quality. The significant trend across quartiles indicated that the odds of poor sleep quality increased with increasing night-shift exposure.

The restricted cubic spline analysis presented in Figure 1 shows a monotonic increase in the adjusted probability of poor sleep quality as monthly night shift frequency increased. The continuous exposure response pattern was consistent with the categorical analysis presented in Table 6 indicating that greater night-shift exposure was associated with progressively poorer sleep quality across the observed range of exposure.

Table 6. Dose response relationship between night-shift exposure and poor sleep Quality (N = 411), Outcome: Poor sleep quality (PSQI >5), Reference group: Q1 (lowest night-shift exposure)

Night-shift quartile	Adjusted OR (AOR)	95% CI	p-value
Q1 (lowest)	1.00	Reference	—
Q2	1.28	0.72–2.27	0.397
Q3	1.79	1.02–3.14	0.041
Q4 (highest)	2.63	1.48–4.67	<0.001

Adjusted odds ratios (AORs) for poor sleep quality according to quartiles of night-shift exposure among healthcare workers. Odds ratios were adjusted for age, sex, occupational group, service category, shift schedule, shift duration, and overtime work. The lowest quartile of night-shift exposure (Q1) served as the reference category. A significant positive trend was observed across quartiles (p for trend < 0.001) indicating progressively higher odds of poor sleep quality with increasing night-shift burden.

3.7 Analysis of individual sleep domains

Individual PSQI components showed that greater night-shift exposure was associated with several dimensions of sleep quality (Table 7). The strongest associations were observed for sleep duration,

sleep efficiency, sleep disturbances, and daytime dysfunction, whereas the remaining PSQI components showed little evidence of association after adjustment. Detailed regression estimates for each PSQI component are presented in Table 7.

Table 7. Associations between shift-work characteristics and individual PSQI component scores among healthcare workers (N = 411)

Outcome (PSQI Component)	Predictor	Adjusted β	95% CI	p-value
Sleep latency	Shift schedule	-0.072	-0.192 to 0.049	0.243
	Night shifts/month	0.001	-0.015 to 0.017	0.882
	Overtime/month	0.003	0.001 to 0.005	0.010
Sleep duration	Shift schedule	-0.099	-0.210 to 0.012	0.079
	Night shifts/month	0.022	0.007 to 0.037	0.004
	Overtime/month	0.000	-0.002 to 0.001	0.629
Sleep efficiency	Shift schedule	-0.048	-0.167 to 0.071	0.430
	Night shifts/month	0.020	0.004 to 0.036	0.013
	Overtime/month	-0.001	-0.003 to 0.001	0.498
Sleep disturbances	Shift schedule	-0.018	-0.082 to 0.047	0.592
	Night shifts/month	0.023	0.015 to 0.031	<0.001
	Overtime/month	-0.001	-0.003 to -0.000	0.012
Daytime dysfunction	Shift schedule	-0.118	-0.270 to 0.034	0.127
	Night shifts/month	0.037	0.016 to 0.057	<0.001
	Overtime/month	-0.001	-0.003 to 0.002	0.605

Adjusted for age and sex. Positive β coefficients indicate poorer sleep outcomes (higher PSQI component scores).

3.8 Exploratory Path Analysis of Potential Mechanisms Linking Shift Work and Sleep Quality

Results demonstrated that shift schedule was associated with monthly night-shift frequency, which in turn was associated with longer sleep latency and poorer overall sleep quality (Figure 2). In addition to this indirect pathway, monthly night-shift frequency showed a direct association with global PSQI score, demonstrating both direct and indirect associations with global PSQI score. Overall, the model demonstrated acceptable fit to the data, supporting the plausibility of the proposed pathway structure. Standardized path coefficients and model fit indices are presented in Figure 2.

4. Discussion

4.1 Principal findings

This study investigated the association between shift-work characteristics and sleep quality among healthcare workers. Poor sleep quality was highly prevalent in the study population, with cumulative night-shift exposure emerging as the strongest independent predictor after adjustment for demographic and occupational characteristics. Increasing monthly night-shift frequency was associated with progressively higher odds of poor sleep quality demonstrating a clear dose response relationship.

Domain-specific analyses showed that greater night-shift exposure was associated with shorter sleep duration, poorer sleep efficiency, increased sleep disturbances, and greater daytime dysfunction. In addition, the exploratory path analysis supported a biologically reasonable pathway linking cumulative night-shift exposure, prolonged sleep latency, and poorer overall sleep quality. These findings suggest that cumulative night-shift burden is a key occupational determinant of sleep impairment among healthcare workers.

4.2 Night-shift burden as the main determinant of poor sleep

The present study identified monthly night-shift frequency as the principal independent predictor of poor sleep quality among healthcare workers. Although longer shift duration and overtime workload also remained associated with poor sleep, the frequency of night shifts showed the strongest association, indicating that repeated exposure to night work is a more important determinant of sleep impairment than occupational role or work setting alone. Furthermore, the dose response analysis demonstrated progressively higher odds of poor sleep quality with increasing night-shift exposure, providing evidence of a graded exposure response relationship.

These findings are consistent with previous epidemiological studies reporting poorer sleep among healthcare workers with frequent night-shift schedules [8, 11, 18]. However, whereas many earlier studies compared shift workers with day workers, our study quantified night-shift exposure and demonstrated a graded relationship across increasing exposure levels. This finding strengthens the epidemiological evidence that greater night-shift exposure is an important occupational determinant of poor sleep quality.

4.3 Sleep domains most affected by shift work

Our study showed that the adverse effects of night-shift work extended beyond overall sleep quality to several key dimensions of sleep. Greater night-shift exposure was independently associated with shorter sleep duration, poorer sleep efficiency, increased sleep disturbances, and greater daytime dysfunction, indicating that cumulative night work compromises both nocturnal recovery and daytime functioning. These findings suggest that the impact of shift work is multidimensional rather than confined to a single aspect of sleep.

Among the individual components, sleep duration and sleep efficiency appeared to be the most affected, reflecting reduced recovery sleep and fragmented sleep following repeated night shifts. Increased sleep disturbances further indicate poorer continuity of sleep, while greater daytime dysfunction highlights the practical consequences of inadequate sleep, including fatigue, reduced alertness, and impaired work performance. Similar patterns have been reported among healthcare workers and other shift-working populations, where shorter sleep duration and poorer sleep efficiency were consistently associated with rotating and night-shift schedules [19, 20]. Descriptive comparisons of shift versus non-shift healthcare workers have variably identified sleep latency [20], a combination of latency, duration, and medication use [15] or efficiency and daytime dysfunction as the domains most affected [13].

Compared with previous studies that relied primarily on the global PSQI score, the present study provides a more detailed assessment of the specific sleep domains affected by cumulative night-shift exposure. This domain-specific approach identifies potential targets for workplace interventions aimed at improving recovery, reducing fatigue, and maintaining cognitive performance and patient safety among healthcare workers [12].

4.4 Biological interpretation of the exploratory path model

The exploratory path analysis provides additional support for the biological plausibility of the associations observed in the multivariable and dose–response analyses. Rather than suggesting a simple direct relationship between night-shift work and sleep quality, the model indicates that cumulative night-shift exposure may impair global sleep quality through disruption of sleep initiation, reflected by prolonged sleep latency. Although the cross-sectional design precludes causal inference, this pathway is consistent with current understanding of sleep regulation.

The proposed pathway accords with established evidence that repeated night work disrupts the normal interaction between circadian timing and sleep homeostasis. Circadian misalignment resulting from working during the biological night delays sleep initiation, reduces the opportunity for restorative daytime sleep, and promotes cumulative sleep debt over successive work cycles [6, 7, 21]. Consequently, prolonged sleep latency may represent an early manifestation of circadian disruption that contributes to poorer overall sleep quality.

Our path model also supports the concept that the effects of night-shift work develop through interconnected physiological processes rather than isolated disturbances in sleep. Previous research has shown that circadian disruption is accompanied by alterations in melatonin and cortisol secretion, sympathetic activation, and inflammatory responses, all of which may impair sleep continuity and recovery [9, 22, 23]. Although these biological markers were not measured in the present study, the observed pathways are consistent with these established mechanisms.

The exploratory path analysis should therefore be interpreted as hypothesis-generating rather than confirmatory. However, the consistency between the path model, the multivariable regression, the dose response analysis, and current biological evidence strengthens the interpretation that cumulative night-

shift burden disrupts normal sleep regulation and contributes to poor sleep quality among healthcare workers. Future longitudinal studies incorporating objective sleep measures and circadian biomarkers are needed to confirm these proposed pathways.

4.5 Comparison with Previous Studies

The findings of the present study are consistent with extensive evidence demonstrating that night-shift work is associated with poorer sleep quality among healthcare workers. Previous systematic reviews and cohort studies have consistently reported that workers exposed to night shifts experience shorter sleep duration, poorer sleep quality, and greater daytime fatigue than permanent day workers [10, 11, 24]. Our findings support this evidence and further indicate that the frequency of night-shift exposure is a more informative indicator of sleep impairment than shift-work status alone.

The present study extends previous research by demonstrating a clear dose response relationship between cumulative night-shift exposure and poor sleep quality while also identifying the specific sleep domains most affected by shift work. By integrating multivariable regression, dose-response modelling, restricted cubic spline analysis, domain-specific assessment of the PSQI, and exploratory path analysis, this study provides a more comprehensive evaluation of the relationship between night-shift work and sleep quality than conventional comparisons between day and shift workers. These findings strengthen the evidence that cumulative night-shift burden is a regulating occupational exposure and support interventions aimed at reducing excessive night-shift schedules to improve sleep health among healthcare workers.

4.6 Occupational health implications

The findings of the present study have important implications for occupational health practice in healthcare settings. The identification of cumulative night-shift exposure as the principal determinant of poor sleep quality suggests that interventions should focus not only on reducing total working hours but also on limiting the frequency and cumulative burden of night shifts. Work schedules that minimize consecutive night duties, provide adequate recovery periods between shifts, and adopt forward-rotating shift patterns may help reduce sleep disruption and improve worker well-being.

Routine assessment of sleep health should be incorporated into occupational health surveillance programs for healthcare workers. Periodic screening using validated instruments, such as the Pittsburgh Sleep Quality Index, may facilitate the early identification of workers at increased risk of sleep impairment and enable timely implementation of preventive measures, including fatigue management, sleep education, and individualized scheduling adjustments. Such interventions may be particularly beneficial for employees with frequent night-shift exposure.

Improving sleep health is likely to have benefits that extend beyond individual well-being. Sleep impairment has been associated with reduced alertness, impaired cognitive performance [3], occupational injuries, and medical errors, all of which may adversely affect patient safety and healthcare

quality [5]. Therefore, optimizing night-shift schedules should be considered an integral component of occupational risk management and patient safety initiatives [4]. Policies that monitor cumulative night-shift exposure and incorporate evidence-based fatigue risk management strategies may contribute to a healthier workforce while supporting safer and more effective healthcare delivery [25].

4.7 Strengths and limitations

This study has several strengths. It included a relatively large sample of healthcare workers selected using a probability-based sampling strategy and employed a validated measure of sleep quality. In addition to conventional multivariable logistic regression, the study incorporated dose–response modelling, restricted cubic spline analysis, domain-specific evaluation of PSQI components, and exploratory path analysis, providing a comprehensive assessment of the relationship between cumulative night-shift exposure and sleep quality.

Several limitations should also be considered. First, the cross-sectional design precludes establishing temporal or causal relationships. Second, sleep quality was assessed using self-reported data and may therefore be subject to recall or reporting bias. Finally, although major occupational and demographic factors were adjusted for, residual confounding from unmeasured variables, such as chronotype, mental health status, caffeine consumption, and use of sleep medications, cannot be excluded. Future longitudinal studies incorporating objective sleep measures and circadian biomarkers are warranted to confirm the observed associations and clarify the underlying mechanisms.

5. Conclusion

Our study extended previous research by demonstrating that cumulative night-shift exposure exhibits a dose-dependent relationship with poor sleep quality and differentially affects multiple dimensions of sleep. The integration of detailed work-schedule characterization with multivariable epidemiological modelling, dose response analyses, restricted cubic spline modelling, and exploratory mechanistic pathway analysis provided a comprehensive understanding of how shift work influences sleep than conventional cross-sectional investigations based on global sleep quality measures. By addressing cumulative night-shift exposure through evidence-based workforce planning, healthcare organizations have the opportunity to enhance employee well-being, strengthen workforce sustainability, and improve the quality and safety of patient care. Our findings support the incorporation of quantitative measures of night-shift burden into future occupational health research and reinforce the importance of considering cumulative exposure when evaluating the health effects of non-standard working hours.

Future longitudinal and multicenter studies incorporating objective sleep assessments, circadian biomarkers, and repeated measurements of work schedules may confirm the relationships observed in the present study and further explain the biological mechanisms through which cumulative night-shift exposure contributes to chronic sleep impairment. Such evidence will be essential for informing evidence-based scheduling policies and occupational health interventions that protect both healthcare workers and the patients they serve.

Abbreviations

Pittsburgh Sleep Quality Index (PSQI)

One-way Analysis of Variance (ANOVA)

Odds ratios (ORs)

Confidence Intervals (CIs)

Adjusted Odds Ratios (AORs)

Area Under the Curve (AUC)

Variance Inflation Factors (VIFs)

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of Semnan University of Medical Sciences, Semnan, Iran with approval number IR.SEMUMS.REC.1400.288. The healthcare workers provided written informed consent to participate in the study. All methods/study procedures were carried out in accordance with the ethical principles of the Declaration of Helsinki. All participants were informed about the purpose of the study, assured of confidentiality, and provided written informed consent prior to participation. Participation was voluntary, and respondents could withdraw at any time without consequence.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' contributions

MBK contributed to the conceptualization, data curation, formal analysis, methodology, visualization, and writing of the original draft, and contributed to reviewing and editing the manuscript. ZSH contributed to data curation, investigation, and writing of the original draft. MM contributed to investigation, formal analysis, and reviewing and editing the manuscript. AD contributed to conceptualization, supervision, investigation, validation, and writing of the original draft, and contributed to reviewing and editing the manuscript. All authors read and approved the final manuscript.

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Figures

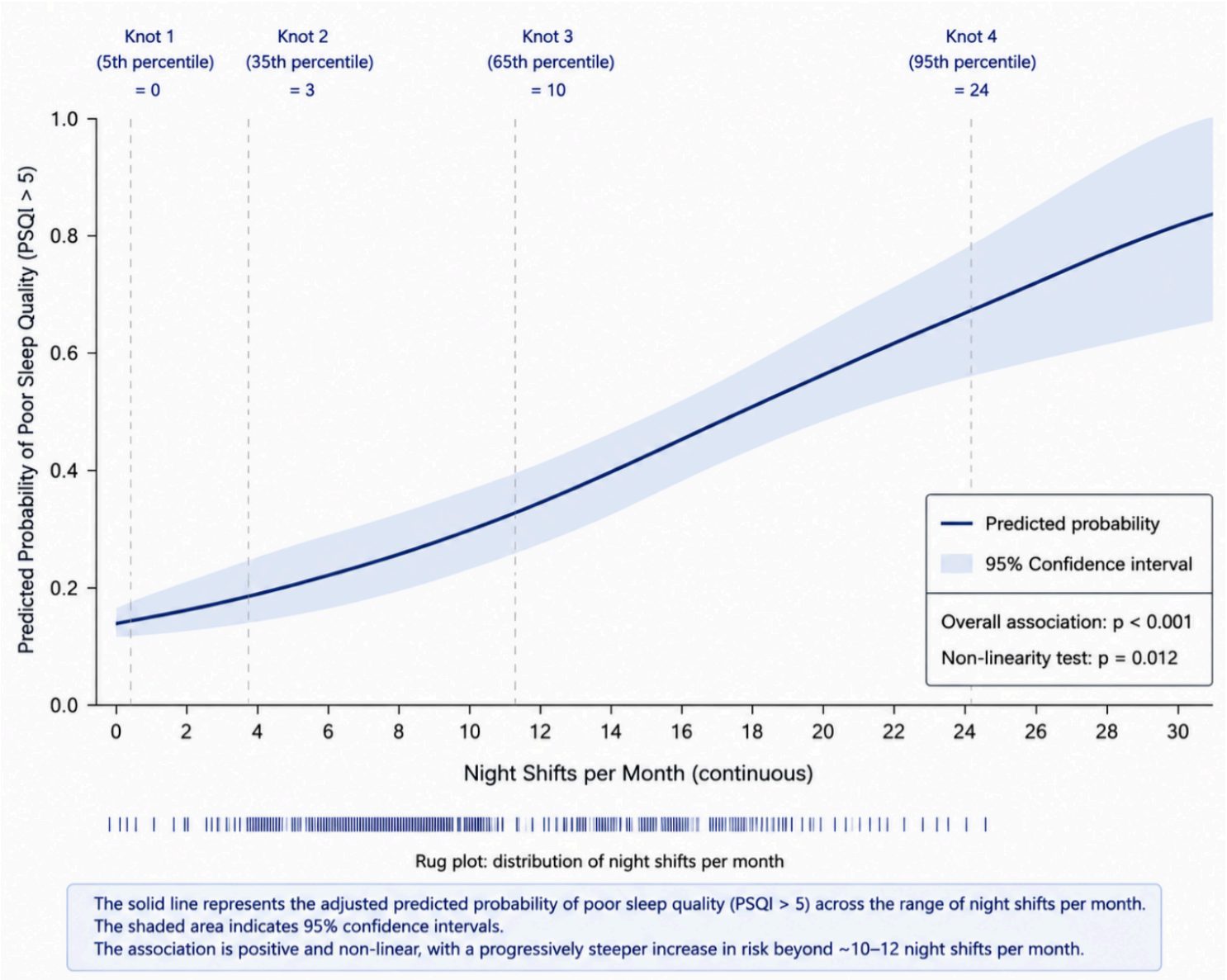
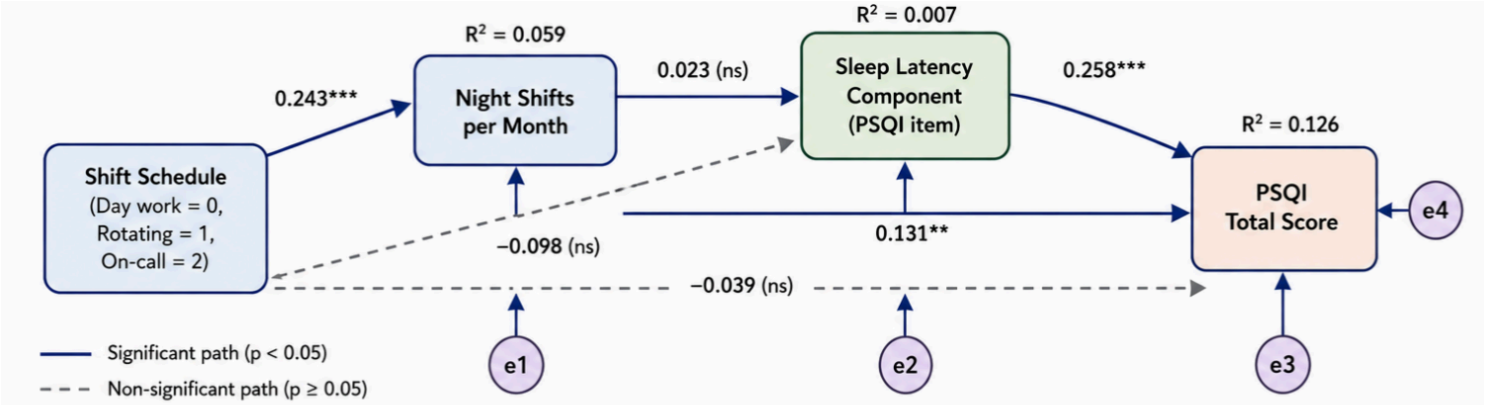


Figure 1

Restricted cubic spline of night shifts per months and predicted probability of poor sleep quality



STANDARDIZED DIRECT EFFECTS (β)	
Shift Schedule → Night Shifts/Month	0.243***
Night Shifts/Month → Sleep Latency	0.023 (ns)
Sleep Latency → PSQI Total Score	0.258***
Night Shifts/Month → PSQI Total Score	0.131**
Shift Schedule → Sleep Latency	−0.098 (ns)
Shift Schedule → PSQI Total Score	−0.039 (ns)

INDIRECT EFFECTS (β)	
Shift Schedule → Night Shifts → Sleep Latency → PSQI	0.001
Shift Schedule → Night Shifts → PSQI	0.032
Total Indirect Effect (Shift Schedule → PSQI)	0.033

TOTAL EFFECTS ON PSQI TOTAL SCORE (β)	
Shift Schedule	−0.006
Night Shifts/Month	0.137
Sleep Latency Component	0.258

MODEL FIT INDICES	
χ^2 (df)	8.21 (3)
χ^2/df	2.74
CFI	0.984
TLI	0.951
RMSEA (90% CI)	0.065 (0.024–0.109)
SRMR	0.028

Values are standardized path coefficients (β). R^2 indicates proportion of variance explained for each endogenous variable.
*** p < 0.001, ** p < 0.01, * p < 0.05, ns = not significant (p ≥ 0.05)
PSQI = Pittsburgh Sleep Quality Index

Figure 2

Structural Equation Model of the pathways linking shift work characteristics to sleep quality (PSQI total score)