

The Impact of Night Shifts on Cardiovascular Function and Occupational Burnout Among Healthcare Workers: A Prospective Controlled Study

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Abstract

Objective—This study aimed to explore the impact of night shifts on cardiac function and occupational burnout among healthcare workers, providing evidence-based recommendations for their health management.

Methods:Sixty healthcare workers were prospectively enrolled and divided into a night shift group (n=29) and a day shift group (n=31) according to night shift participation. Echocardiographic and 24-hour Holter monitoring data were collected from the night shift group on the day of rest and 3 days later, as well as from the day shift group. Fatigue, stress, and job burnout questionnaires were administered. Echocardiographic parameters, heart rate variability (HRV) indices, and questionnaire scores were compared between groups.

Results:Cardiac function analysis showed the night shift group had significantly lower Left Ventricular Ejection Fraction (LVEF), Tricuspid Valves' Tricuspid Annular Plane Systolic Excursion (TVs'), and Global Longitudinal Strain (GLS) than the day shift group on rest days. After three days' rest, TVs' 11.71 ± 1.19 vs. 12.47 ± 1.27 , SDD=1.32; TAPSE 21.86 ± 1.46 vs. 22.72 ± 1.49 , SDD=1.09; and GLS -21.27 ± 0.73 vs. -22.08 ± 0.79 , SDD=0.68 improved in night shift workers ($P < 0.05$). HRV analysis revealed a higher LF/HF ratio in night shift workers on rest days. Post-rest, their SDNN, SDANN, RMSSD, and VLF increased, though LF/HF remained elevated vs. day shift ($P < 0.05$). Questionnaires showed higher sleepiness, fatigue, and stress scores in night shift workers on rest days, improving after three days. Conversely, day shift group exhibited significantly better performance in occupational burnout status than the night shift group ($P < 0.05$).

Conclusion:Night shift work induces short-term ventricular systolic dysfunction and autonomic dysregulation in healthcare professionals. Three days of post-shift rest partially restores cardiac function and parasympathetic tone, though autonomic function does not fully revert to baseline. Occupational burnout scores also significantly increase in the night shift group.

1. Introduction

- Night shift work, as an important work pattern for maintaining the continuous operation of society, has a prevalence rate of up to 30% among China's working-age population [1], with healthcare workers accounting for a particularly high proportion. Numerous studies have shown that circadian rhythm disruption can lead to abnormalities in neuroendocrine regulation and metabolic dysfunction, making it an independent risk factor for cardiovascular disease [2, 3]. Epidemiological surveys of healthcare workers have shown that the incidence of cardiovascular diseases is significantly higher among shift workers [4, 5], with a clear exposure-response relationship. Longitudinal studies have confirmed that female healthcare workers who have worked night shifts for ≥ 5 years have significantly higher all-cause mortality and cardiovascular disease-specific mortality rates [6].

- The short-term effects of night shift work on cardiovascular function are currently unclear, particularly with regard to whether cardiovascular function can recover during rest periods. Therefore, systematically assessing dynamic changes in cardiovascular function and autonomic nervous system regulation in night-shift healthcare workers and quantifying the effects of rest on the recovery of cardiovascular function holds significant value for the development of targeted night-shift work strategies [7]. This study will compare heart rate variability (HRV) and echocardiogram parameters, as well as occupational burnout scale scores, between night shift workers on the day of night rest and three days after, and between night shift workers before and after night rest, and day shift healthcare workers. This will systematically evaluate the short-term effects of night shift work and recovery after rest, providing a theoretical basis for the scientific management of the occupational health of night shift healthcare workers. Drawing on prior research, we formulated the following hypotheses for the present study:
- H1: Compared with day shifts, night shifts will acutely impair biventricular systolic function—manifested by reduced GLS and TVs’—accompanied by autonomic dysregulation and elevated levels of sleepiness, fatigue, stress, and occupational burnout among healthcare workers.
- H2: A three-day rest period following night shifts will lead to significant recovery of the aforementioned cardiac function parameters and subjective fatigue levels toward baseline values, albeit with potential incompleteness in recovery.

2. Research Methods

2.1. Study Population

- From June 2024 to January 2025, a prospective study was conducted, enrolling 60 healthcare workers engaged in frontline clinical work at the First People's Hospital of Yancheng City in Jiangsu Province as participants. The hospital in this study is a large tertiary general hospital serving a population of over 7 million, with an annual volume of more than 2.3 million outpatient and emergency visits. All departments within the hospital operate on a standardized shift schedule, specifically: day shifts from 08:00 to 17:00 and night shifts from 17:00 to 08:00. Participants were recruited from the Radiology, Emergency Medicine, Anaesthesiology and Pharmacy departments. Participants were categorized into night shift and day shift groups based on their involvement in night shift work. All participants in the night shift group regularly undertook night shift rotations, following a fixed schedule: several consecutive day shifts, 1 night shift, and 3 days of rest. The day shift duration was 9 hours (08:00–17:00), while the night shift lasted 15 hours (17:00–08:00 the next day). In contrast, participants in the day shift group had no history of night shift rotations in the past two years and maintained consistent daily schedules. Their work schedule followed a cycle of 5 consecutive days of day shifts (08:00–17:00, 9 hours) followed by 2 days of rest. For the purposes of this study, the day following the end of night shift work was defined as the night rest day, and the third day following the end of night shift work was defined as the third night rest day. The specific time points at which the night shift group underwent evaluations are illustrated in Fig. 1. The

inclusion criteria for this study were as follows: (1) Engaged in clinical frontline medical work, and (2) had no underlying conditions such as hypertension or diabetes. Exclusion criteria: (1) absence during the study period; (2) pregnancy; (3) During the study period, participants consumed alcohol and caffeine, and engaged in strenuous exercise. (4) poor acoustic window or inability to cooperate with follow-up. In accordance with ethical requirements, the study protocol was reviewed and approved by the hospital ethics committee (approval number 2024-K-37) and informed consent was obtained from all participants.

2.2. Collection and analysis of echocardiography data

The night shift group underwent transthoracic echocardiography on the day of their night rest, and again at 8 a.m. on the third day after their night rest. The day shift group collected transthoracic echocardiography data at 08:00 on working days. A Philips EPIC 7C ultrasound diagnostic device equipped with an X5-1 probe (frequency 1–5 MHz) was used to collect standard left ventricular ultrasound sections (apical four-chamber, long-axis and two-chamber views) in order to observe the structure of the left ventricle. Dynamic images were obtained from three to five consecutive cardiac cycles, with synchronous electrocardiogram recording [8]. All images were acquired by the same experienced technician. For data measurement and analysis, the analysts employed a blinded approach, remaining unaware of the group allocations, to minimize potential bias to the greatest extent possible. Conventional echocardiographic parameters were measured, such as left atrial diameter (LAD) and left ventricular diameter. Left ventricular end-diastolic volume (LVEDV) and left ventricular end-systolic volume (LVESV) were measured separately. The left ventricular ejection fraction (LVEF) was measured using the two-dimensional Simpson method [9]. Launch the in-machine quantitative analysis software QLAB and select the aCMQ mode to analyse the stored echocardiographic dynamic images. Identify and track the endocardium to generate the longitudinal strain-time curve of the left ventricle (Fig. 2) and record the global longitudinal strain (GLS) of the left ventricle [10]. For ease of analysis and description, the left ventricular strain values are expressed as absolute values in this paper.

2.3. Dynamic electrocardiogram data collection and analysis

The night shift group collected 24-hour Holter ECG data on the day of night rest and three days after night rest, while the day shift group collected 24-hour Holter ECG data on working days. All participants used the Nalong Holter ECG recorder (iMED-6400) to record test results and analysed HRV time-domain and frequency-domain parameters using its analysis software. R-R interval time series were extracted from the ECG recordings, and HRV time-domain parameters [11] were calculated, including the standard deviation of normal-to-normal intervals (SDNN) for all sinus beats, standard deviation of all normal NN intervals (SDANN), and root mean square of successive differences of NN intervals for the period of interest (RMSSD) [12]. Spectral analysis was performed using the fast Fourier transform to obtain frequency domain parameters. The frequency range of 0.0033–0.04 Hz is defined as very low frequency

(VLF), 0.04–0.15 Hz as low frequency (LF), and 0.15–0.4 Hz as high frequency (HF), and the LF/HF ratio is calculated. [13].

2.4. Survey on fatigue, stress, and occupational burnout

The present study employed a questionnaire survey method to conduct research on the participants. The survey content comprised assessments using the Karolinska Sleepiness Scale (KSS) and the Stanford Sleepiness Scale (SSS), as well as evaluations of fatigue levels, occupational stress, and occupational burnout status [14]. Among these scales, the Karolinska Sleepiness Scale (KSS) utilizes a 1–9 rating scale to allow participants to self-assess their alertness levels, where a score of 1 indicates extreme alertness and 9 indicates extreme sleepiness. This scale was used to capture transient fluctuations in alertness at the conclusion of a night shift. The Stanford Sleepiness Scale (SSS), in contrast, employs a 7-point rating scale that requires participants to select the option best describing their current sleepiness from seven descriptive statements, and it was used to evaluate the cumulative fatigue load accumulated throughout the entire night shift.[15]. The assessment of fatigue levels and occupational stress was conducted utilising a 10-point self-report scale, with elevated scores denoting heightened levels of current fatigue and stress. The assessment of occupational burnout is predominantly facilitated by the Maslach Burnout Inventory (MBI), a comprehensive instrument encompassing three distinct dimensions: emotional exhaustion, depersonalisation, and a sense of accomplishment [16]. The Emotional Exhaustion subscale comprises nine items, with a score range of 0–54 points; the Depersonalisation subscale comprises five items, with a score range of 0–30 points; and the Personal Accomplishment subscale comprises eight items, with a score range of 0–48 points. A 7-point Likert scale (0 = never, 6 = often) is utilised, with the score for each dimension being the total score of the items. As demonstrated in Fig. 17, elevated scores on the emotional exhaustion and depersonalisation dimensions, and diminished scores on the personal accomplishment dimension, are indicative of more severe occupational burnout [17].

2.5. Statistical methods

The analysis was conducted utilising SPSS 22.0 statistical software. The Shapiro-Wilk test was utilised to evaluate the normality of the data. For variables that met the criteria for normal distribution, data were described as mean $\pm$ standard deviation ($\bar{x} \pm s$). For variables that did not meet the criteria for normal distribution, data were expressed as M(Q1, Q3). The count data comparisons were presented as rates or percentages. A series of parametric comparisons between groups was conducted using t-tests. In addition, a series of comparisons between pre- and post-night shift periods in the night shift group were performed using paired t-tests. All statistical analyses were conducted employing two-sided tests, with a significance level set at $\alpha = 0.05$.

3. Results

3.1. Population Characteristics

A total of 60 healthcare workers who voluntarily participated in this study were enrolled, including 17 radiologists, 8 radiologic technologists, 12 emergency medicine physicians, 8 anesthesiologists, and 15 pharmacists. Among them, the night shift group comprised 29 participants [mean age: 32.24 ± 3.87 years, 14 males], and the day shift group consisted of 31 participants [mean age: 30.97 ± 4.56 years, 11 males]. There were no statistically significant differences between the two groups in baseline characteristics (height, weight, body mass index, age, gender, years of work experience) (P > 0.05), as detailed in Table 1.

Table 1
Population characteristics

Height/cm	night shift group(n = 29)	day shift group(n = 31)	p
	169.97 ± 6.77	167.29 ± 6.61	0.127
Weight/kg	65.97 ± 9.87	61.68 ± 10.33	0.106
BMI/ (kg/m²)	22.73 ± 2.27	21.98 ± 2.99	0.281
Age/years	32.24 ± 3.87	30.97 ± 4.56	0.250
Sex/man	14(48.3)	11(35.5)	0.323
Years of service/years	7.48 ± 3.96	6.26 ± 4.05	0.242
Night Shift tenure/years	6.00 ± 3.67	-	-
Interval between night shifts/days	7.72 ± 1.04	-	-
Night Shift Sleep/h	4.24 ± 0.64	-	-
Note: BMI: Body Mass Index = Weight (kg) / Height² (m²)			

3.2. Analysis of echocardiographic parameters

Compared with the day shift group, the night shift group had lower LVEF, GLS, and TVs' on the day of night rest; however, there was no statistically significant difference in these parameters three days after night rest. Within the night shift group, GLS, TVs', and TAPSE improved three days after night rest compared with the day of night rest (P < 0.05) (Table 2).

Table 2

Comparison of routine echocardiographic parameters between the night shift group on the day of night rest and 3 days after night rest and the day shift group.

	night shift group(n = 29)		day shift group (n = 31)	a _p	b _p	c _p
	the day of night rest	three days after night rest				
LAD/mm	30.10 ± 2.61	30.17 ± 2.30	29.32 ± 2.81	0.774	0.27	0.207
LVDd/mm	45.86 ± 2.63	46.28 ± 2.48	44.90 ± 2.82	0.103	0.179	0.051
LVDs/mm	30.14 ± 2.37	30.69 ± 3.02	29.71 ± 2.77	0.111	0.524	0.195
LVEDV/ml	88.39 ± 16.97	86.24 ± 15.73	81.70 ± 13.96	0.273	0.100	0.242
LVESV/ml	32.99 ± 7.38	31.91 ± 5.66	28.86 ± 6.27	0.255	0.023	0.054
LAVI/mL/m ²	19.84 ± 2.72	19.49 ± 2.57	19.67 ± 2.95	0.237	0.814	0.801
LVEF/%	62.76 ± 3.17	63.04 ± 2.85	64.65 ± 3.59	0.553	0.035	0.060
E/e'	6.33 ± 1.28	6.32 ± 1.60	6.93 ± 1.22	0.972	0.067	0.100
E/A	1.30 ± 0.21	1.34 ± 0.23	1.41 ± 0.38	0.262	0.186	0.412
TVs'(cm/s)	11.71 ± 1.19	12.47 ± 1.27	12.66 ± 1.26	0.004	0.004	0.559
TAPSE/mm	21.86 ± 1.46	22.72 ± 1.49	22.48 ± 1.36	< 0.001	0.093	0.516
GLS	21.27 ± 0.73	22.08 ± 0.79	21.72 ± 0.75	< 0.001	0.022	0.077

Note: LAD: left atrial diameter, LVDd:left ventricular end-diastolic diameter, LVDs: left ventricular end-systolic diameter, LVEDV: end-diastolic volume, LVESV: end-systolic volume, LAVI:left atrial volume index, LVEF: left ventricular ejection fraction, E/A: early to late mitral filling velocity ratio, TVs': systolic motion velocity of the tricuspid annulus, TAPSE: systolic displacement of the tricuspid annulus, GLS: global longitudinal strain of the left ventricle .^aP: three days of night rest versus the day of night rest.^bP: the day of night rest versus the day shift group.^cP: three days of night rest versus the day shift group.

3.3. Heart rate variability parameter analysis

In comparison with the day shift group, the night shift group had higher LF/HF values on the day of night rest and 3 days after night rest (3.03 ± 1.45 vs. 2.02 ± 0.81 , 2.79 ± 1.15 vs. 2.02 ± 0.81 , $P < 0.05$). However,

no statistically significant variations were observed in the time domain parameters. Within the group of individuals working the night shift, the heart rate variability parameters SDNN, SDANN, RMSSD, and VLF were significantly higher three days after night rest in comparison to the day of night rest ($P < 0.05$), as illustrated in Table 3.

Table 3

Comparison of heart rate variability parameters between the night shift group on the day of night rest and 3 days after night rest and the day shift group

	night shift group(n = 29)		day shift group (n = 31)	^a p	^b p	^c p
	the day of night rest	three days after night rest				
SDNN	134.83 ± 25.73	153.28 ± 23.56	142.81 ± 25.09	< 0.001	0.229	0.102
SDANN	129.52 ± 26.04	146.79 ± 29.84	134.26 ± 26.77	0.002	0.490	0.092
PNN50	4.55 ± 4.22	4.90 ± 2.74	6.31 ± 3.96	0.622	0.100	0.261
SDNNindex	38.79 ± 17.95	42.07 ± 15.86	35.26 ± 11.21	0.143	0.369	0.062
RMSSD	31.03 ± 10.04	34.66 ± 8.67	33.74 ± 8.66	0.040	0.267	0.518
VLF	998.32 ± 341.37	1196.38 ± 351.48	1193.33 ± 422.53	0.020	0.055	0.976
LF	742.18 ± 335.32	872.48 ± 346.34	647.99 ± 366.90	0.099	0.305	0.018
HF	302.72 ± 226.60	347.17 ± 172.54	334.68 ± 144.57	0.277	0.515	0.762
LF/HF	3.03 ± 1.45	2.79 ± 1.15	2.02 ± 0.81	0.350	0.002	0.004

Note: SDNN: Standard deviation of all sinusoidal RR intervals, SDANN: Standard deviation of average adjacent RR intervals, PNN50: Percentage of consecutive RR intervals with a difference exceeding 50 ms, SDNN Inde: Average SDNN value every 5 minutes, RMSSD: Root mean square of adjacent RR interval differences, VLF: Very low frequency power, LF: Low frequency power, HF: High-frequency power, LF/HF: Low-frequency to high-frequency power ratio. ^aP: three days of night rest versus the day of night rest. ^bP: the day of night rest versus the day shift group. ^cP: three days of night rest versus the day shift group.

3.4. Assessment of fatigue, stress and occupational burnout

On the rest day, the night shift group scored significantly lower than the day shift group on both the Karolinska Sleep Scale (KSS) and the Stanford Sleepiness Scale (SSS) ($P < 0.05$). Significant intergroup differences were also observed in fatigue levels and occupational stress scores ($P < 0.05$). However,

after three consecutive days of nocturnal rest, these disparities vanished; statistical analysis indicated that the differences were no longer significant ($P > 0.05$). Notably, within the night shift cohort, all scale scores improved significantly after three nights of rest compared to a single night, with statistical significance at the 0.05 level ($P < 0.05$). Using the Maslach Burnout Inventory (MBI), the night shift group demonstrated significantly higher scores in emotional exhaustion and depersonalization dimensions, and significantly lower personal accomplishment scores, relative to the day shift group ($P < 0.05$). The detailed data are tabulated in Table 4.

Table 4

Comparison of night shift workers on the day of night rest and three days after night rest with day shift workers on the questionnaire and occupational burnout

	night shift group(n = 29)		day shift group (n = 31)	^a P	^b P	^c P
	the day of night rest	three days after night rest				
scale scoring						
KSS	5.62 ± 1.05	4.17 ± 1.00	4.39 ± 1.12	< 0.001	< 0.001	0.437
SSS	4.31 ± 1.04	3.17 ± 0.89	3.35 ± 1.02	< 0.001	0.001	0.464
fatigue	4.90 ± 1.26	3.45 ± 1.45	3.74 ± 1.50	< 0.001	0.002	0.446
stress	4.14 ± 1.25	3.21 ± 1.50	3.00 ± 1.32	< 0.001	0.001	0.571
MBI						
Emotional exhaustion	-	19.29 ± 4.58	16.42 ± 3.53	-	-	0.009
Depersonalization	-	7.96 ± 3.04	5.29 ± 2.08	-	-	< 0.001
Personal Accomplishment	-	38.36 ± 3.50	40.13 ± 2.38	-	-	0.025
Note: KSS, Karolinska Sleepiness Scale. SSS, Stanford Sleepiness Scale. The fatigue and stress survey scale uses a 10-point scale. ^a P: three days of night rest versus the day of night rest. ^b P: the day of night rest versus the day shift group. ^c P: three days of night rest versus the day shift group.						

4. Discussion

Recent epidemiological studies have confirmed that long-term night shift work may increase the risk of cardiovascular disease among night shift workers [18]. The precise mechanisms underlying this phenomenon remain to be elucidated; however, the following factors may be contributing factors: the

sustained elevation of sympathetic nervous system activity caused by circadian rhythm disruption from night shift work [19], the suppression of melatonin secretion by the pineal gland due to exposure to light at night [20], and the long-term chronic inflammation triggered by elevated concentrations of inflammatory factors in plasma [21, 22]. Consequently, the repercussions of night shift work on the cardiovascular system are predominantly protracted and chronic [23], while the immediate consequences and the recuperation of cardiovascular function subsequent to adequate rest remain ambiguous. The present study investigated the short-term effects of night shift work on the cardiac structure and function of healthcare workers, and their recovery after adequate rest. The findings of the study demonstrate that night shifts have detrimental effects on the cardiovascular system and subjective fatigue. However, occupational burnout and autonomic nervous system dysfunction persisted, indicating incomplete recovery of autonomic nervous system function and psychological stress. A prior study revealed that two consecutive days of rest are insufficient for nursing staff to fully recover from night shifts[24].It is hypothesized that an extended rest period beyond three days may promote further recovery of the autonomic nervous system. Our findings support and fully validate our primary hypothesis. After three days of night rest, the night shift group showed significant improvements in TVs' (11.71 ± 1.19 vs. 12.47 ± 1.27 , SDD = 1.32), TAPSE (21.86 ± 1.46 vs. 22.72 ± 1.49 , SDD = 1.09), and GLS (21.27 ± 0.73 vs. 22.08 ± 0.79 , SDD = 0.68) improved compared to the day of night rest.

This study systematically evaluated the echocardiographic alterations in night shift medical workers. The investigation revealed that LVEF, GLS, and TVs' exhibited a statistically significant decrease in the night shift group on the day of night rest in comparison with the day shift group. Although minor differences were observed in echocardiographic parameters—including GLS, TVs', and TAPSE—between day-shift and night-shift workers, as well as between individuals assessed on the day after night shifts and those evaluated after three days of rest, it remains unclear whether these differences hold clinical significance. Previous studies have reported findings consistent with ours [25], which underscores the value of presenting the conclusions of this study. Furthermore, all participants across study groups exhibited left ventricular ejection fraction (LVEF) within the normal range, which may partially explain the limited magnitude of the observed differences..The above findings indicate that night shift work may induce subclinical impairment of left and right ventricular systolic function in healthy individuals.However, it is demonstrated that short-term rest can effectively restore left and right ventricular systolic function. This finding is consistent with the conclusions of Bingol et al.'s study on acute sleep deprivation [26], which collectively substantiates the reversal effect of brief periods of rest on cardiac subclinical damage. The findings of increased sympathetic activity in HRV on the day of night rest (higher LF/HF ratio) may be indicative of excessive sympathetic nervous system activation [27], however further research is required to elucidate the precise mechanisms.

The findings of this study demonstrated that the left atrial volume index (LAVI) remained stable both prior to and following night shifts. This finding is consistent with the observations reported by Cincin et al., who examined the effects of acute sleep deprivation on the left atrium. Their findings indicated that short-term night shift work may not result in substantial left atrial remodelling [28].

HRV analysis revealed that the LF/HF ratio was significantly higher in the night shift group on the day of the night shift compared to the day shift group, suggesting reduced parasympathetic activity and sustained sympathetic activity [29]. This result may be attributed to the disruption of circadian rhythms caused by acute sleep deprivation, which affects the regulation of the hypothalamic pacemaker and suppresses the activity of parasympathetic nuclei. This is consistent with the pattern of acute suppression reported in emergency physicians following 24-hour shifts[30]. Following a three-day period of nocturnal rest, the night-shift group exhibited substantial increases in SDNN, SDANN, RMSSD, and VLF in comparison to the day of the night shift, suggesting an augmentation in parasympathetic activity. However, the absence of disparities in time-domain parameters in this study suggests that short-term rest may partially restore autonomic nervous system function. The differences in frequency-domain parameters, on the other hand, require further research to explore their clinical significance. Furthermore, following a three-day period of nocturnal rest, LF/HF remained significantly elevated in comparison to the day-shift group. This finding is partially consistent with the results of Hulsege et al., indicating that night shift work may lead to autonomic nervous system imbalance [31].

- The results of the study's questionnaire scores indicate that following a 3-day recovery period, the KSS, SSS scores, and fatigue and stress scores of the night shift group improved significantly in comparison to the day of the night shift. However, no significant differences were observed in comparison to the day shift group. This finding indicates that adequate rest, when taken in the short term, can effectively reverse the acute fatigue state and subjective stress feelings caused by night shift work. However, sleepiness scale scores increased significantly after night shifts, which may be associated with parasympathetic activity rebound following prolonged night shifts [32]. Parasympathetic rebound induces the release of large amounts of acetylcholine via the nucleus tractus solitarius (NTS)-dorsal vagal nucleus pathway, which significantly inhibits the activity of locus coeruleus noradrenergic neurons and the hypothalamic orexin system, ultimately resulting in acute sleepiness. However, MBI scores demonstrated that emotional exhaustion and depersonalisation scores in the night shift group remained significantly higher than those in the day shift group, while personal accomplishment scores were lower [33]. This finding suggests that psychological burnout resulting from night shift work may be attributable to long-term occupational stress accumulation, which is characterised by dysfunction of the hypothalamic-pituitary-adrenal axis and chronic inflammatory responses [34]. Such conditions may not be fully reversed by short-term recovery alone.

- *Study Limitations and Future Research Directions*

This study has certain limitations. First, the sample was restricted to 60 young, healthy healthcare workers, with 29 in the night shift group. This narrow sampling frame limits the generalizability of the findings, as they cannot be extended to older populations or individuals with chronic diseases. Future studies should therefore expand the sample size and include participants with underlying medical conditions. Second, all participants were recruited from a single hospital, which may have introduced both occupational exposure homogeneity and selection bias, further constraining the external validity of

the results. Third, the study did not track or record participants' physical activity levels, dietary patterns, or nutritional intake—factors that could potentially confound the observed associations. Future research should collect such information via structured questionnaires to enhance the robustness of the analysis.

To address these limitations, future studies plan to broaden the population coverage, adopt a multicenter collaborative design, and conduct stratified analyses. Additionally, efforts will be made to develop a predictive model for cardiovascular risk in night shift workers, integrating comprehensive demographic, lifestyle, and clinical data to improve its accuracy and applicability.

5. Conclusions

The present study hypothesises that short-term night shifts can lead to subclinical damage to ventricular function in healthcare workers, as well as autonomic nervous system dysfunction, manifested as increased sympathetic nervous activity. It has been demonstrated that adequate rest after night shifts can improve healthcare workers' subjective acute fatigue and stress levels. Furthermore, it has been shown that this can partially improve parasympathetic nervous system function and exerts a certain subclinical restorative effect on ventricular systolic function. It is worth noting that this study observed that recovery remained incomplete three days after night shift rest. However, as follow-up assessments were not continued beyond the three-day rest period, the underlying cause of this phenomenon could be either insufficient rest duration or the inherent chronic effects of long-term night shift work patterns—this requires further investigation to confirm. The findings of this study provide healthcare institutions with important evidence for the optimisation of shift schedules and health management.

Declarations

Author Contributions: Conceptualization, J.Q., X.W., and J.Y.; data gathering, J.Q.; Y.C.; R.C.; writing—original draft preparation, J.Q.; writing—review and editing, X.W., and J.Y.; supervision, J.Y.; final approval, all authors. All authors have read and agreed to the published version of the manuscript.

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of Helsinki, as revised in 2013. Ethical approval for the study was granted by the First People's Hospital of Yancheng City on 30 May 2024. (Approval number: 2024-k-137). It was just an observational study without treatment and only involved volunteers. Data were kept anonymous and confidential during all stages of the study.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflict of interest.

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Figures

	night shift work	three days after night rest			Day shift work	
Time	17:00	8:00	8:00	8:00	8:00	8:00
Echo		✓			✓	
24h Holter		↔			↔	
Fatigue and sleepness		✓			✓	
MBI		✓			✓	

Figure 1

Overview of Night Shift Research Design.

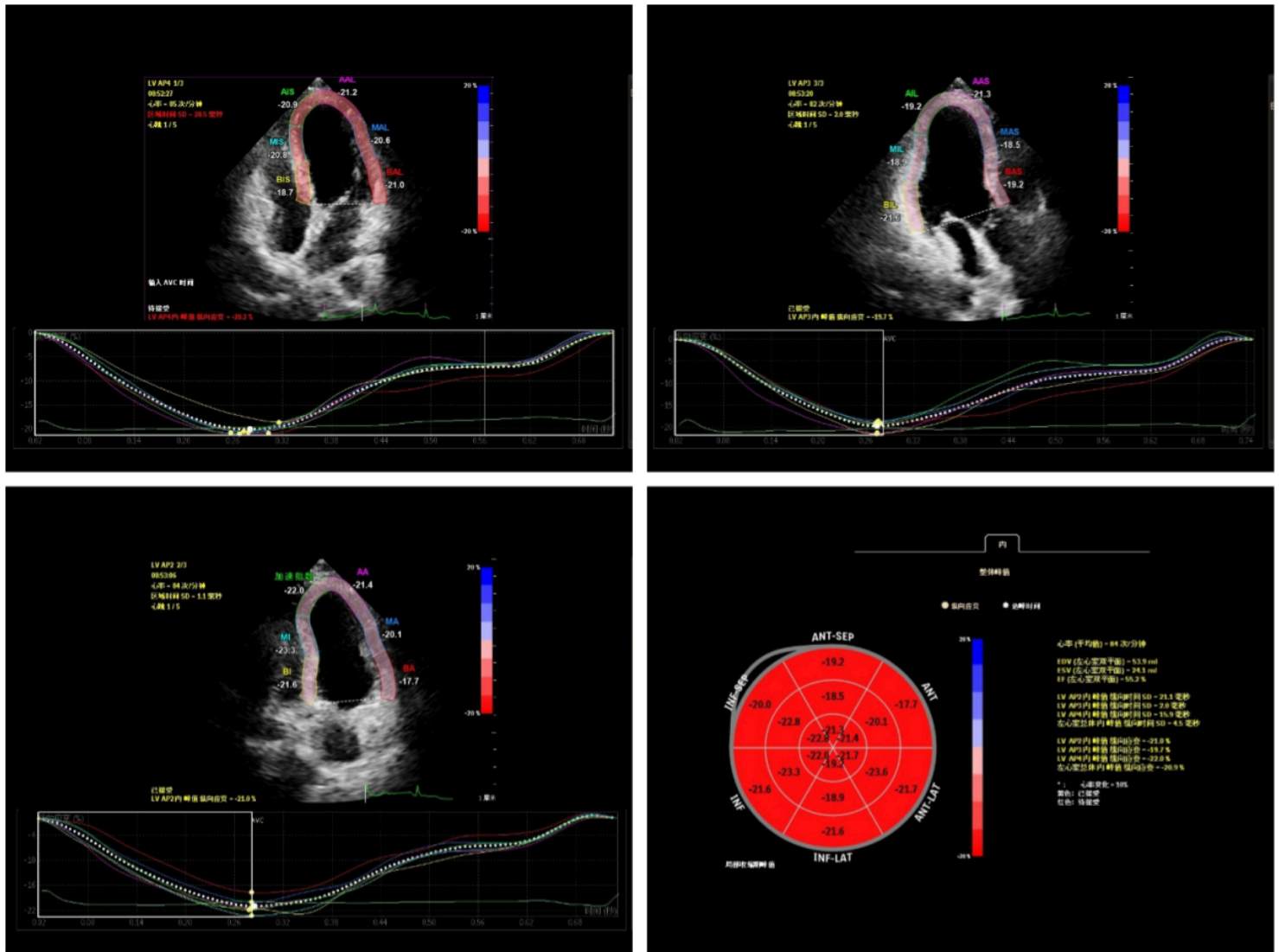


Figure 2

Longitudinal strain of each segment of the left ventricle and bull's-eye diagram

Note: Measurement of longitudinal myocardial strain during systole using two-dimensional speckle tracking (2DSTE) in the four-chamber, three-chamber, and two-chamber views.