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The effect of different shift work systems on the physiological and psychological health of clinical nursing staff: Evidence on heart rate variability

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Abstract

In this study we assessed clinical nursing staff's health in terms of overall heart rate variability and overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity, under different shift-work systems. There were no significant differences between non-shift work and permanent shift work on clinical nursing staff's health. However, the health of clinical nursing staff working non-permanent shifts was significantly worse. Our results suggest that clinical nursing staff should be prevented from working non-permanent shifts, even when nursing resources are lacking.

Keywords: clinical nursing staff, shift work, nursing management, heart rate variability

1 Introduction

Because clinical nursing care is required for hospital patients 24 hours a day, it is necessary for clinical nursing staff to work in shifts. However, shift work may cause abnormalities in clinical nursing staff's circadian rhythms and be detrimental to their health. When nursing staff suffer poor health, the quality of their work deteriorates, and this could motivate clinical nursing staff to resign. Thus, it is important for nursing management to adapt shift-work systems in order to prevent these potentially negative consequences.

In this study we assess clinical nursing staff's health in terms of overall heart

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rate variability and overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity, under different shift-work systems.

The United States Department of Labor defines shift work as the portion of working time that is outside the period between eight in the morning and four o'clock in the afternoon. The International Labour Organization (ILO) defines shift work as "a method of organization of working time in which workers succeed one another at the workplace so that the establishment can operate longer than the hours of work of individual workers" (World of Work Report, 2013). This means that shift work requires the separation of employees into several teams, with each team working at different times and rotating their working times cyclically. In the literature, there are five types of shift work, namely permanent shifts, rotating shifts, oscillating shifts, split shifts and relief shifts (Benjamin, 1984; White & Keith, 1990). The main shift-work types for clinical nursing staff are permanent shifts and rotating shifts. Thus, for this study, we divided our sample into three sub-groups, i.e. non-shifts, permanent shifts and non-permanent shifts, to test the effects of different types of shift work on the health of clinical nursing staff.

Suzuki et al. (2004), Niu et al. (2011) and Zhao et al. (2011) tested the effects of shift work on clinical nursing staff's health from the viewpoint of mental health status, sleep quality and weight. They found that shift work causes obesity, sleep disorders and stress. Clinical research has related obesity, sleep disorders and psychological stress to parasympathetic activity (Hirsch et al. 1991; Zahorska et al. 1993; Kageyama et al. 1997; Martini et al. 2001; Faulkner et al. 2003; Stein & Pu 2012). Heart rate variability (HRV), the periodic changes in a person's heartbeat, is controlled by the parasympathetic system. Therefore, through an analysis of changes in HRV, it is possible to understand the relationship between shift-work systems and psychogenic health risks. Heartbeat is regulated and controlled by a fixed discharge frequency of sinoatrial node cells and the autonomic nervous system. Given the combined functions of the sympathetic and parasympathetic nervous systems, a person's heart rate will show different degrees of variability (Akselrod et al. 1981). Changes in HRV are considered a risk factor for cardiovascular disease (Tsuji et al. 1996; Thayer et al. 2010). Therefore, HRV is regularly used as an evaluation index for the probability of angina, myocardial infarction, coronary heart disease, heart failure and psychogenic death (Tsuji et al. 1996; Doulalas et al. 2001).

Through the analysis of changes in HRV, we can measure psychological problems in clinical nursing staff. According to long-term surveys, anxiety is relative to the disability of the autonomic nervous system (Miu et al., 2009; Andruskevicius et al., 2009). Licht et al. (2008) and Licht et al. (2009) also found that anxiety is relative to decreases in HRV, and decreases in HRV can predict psychological dysfunction. Furthermore the potential for cardiac death increases with anxiety and worry. Martens et al. (2008) conducted research regarding the effect of anxiety on cardiac function and observed their subjects' HRV. They found that anxiety influences the parasympathetic system's control of heartbeat and as such, anxiety is a dangerous element that results in a poor health prognosis. Carney

and Freedland (2009) investigated the effects of depression in patients who suffered from coronary artery disease (CAD). They determined that there is a significant relationship between HRV and depression in CAD patients.

In light of the above research, it is feasible to measure the differences in clinical nursing staff's physiological and psychological health by analyzing changes in HRV. In this study, we used the results of overall heart rate variability and overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity, to investigate the differences in clinical nursing staff's physiological and psychological health when working non-shifts, permanent shifts and non-permanent shifts.

2 Materials & Methods

The sample population in this research comprised 138 clinical nursing staff from a mental teaching hospital and a chest hospital. The research period ran from 1 January to 31 December 2010, and the data frequency was monthly. The subjects had their heart rate measured with a cardiograph after work, a recording process that lasted five minutes. The following parameters were recorded to analyze overall HRV and overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity: heart rate (HR; bpm), mean R wave to R wave (RR) intervals (ms), standard deviation of RR intervals (SDDN; ms), the percentage of the difference between adjacent RR intervals of more than 50 ms and Bethe total RR intervals (PNN50; %), total power (TP; ms^2), low frequency/high frequency (LF/HF), very low frequency peak (VLFH; Hz), very low frequency power (VLF; ms^2), low frequency peak (LFH; Hz), low frequency power (LF; ms^2), normalized high frequency (HFnom; nU), LF max power (LFmax; see^2/Hz) and HF max power (HFmax; see^2/Hz).

Our results were tabulated as normal or exceptional (abnormal). We adapted a binary logistic regression model to test our arguments, and the model setting were presented in Appendix.

3 Results

Table 1 shows the descriptive statistics of the subjects' demographic information, including age, gender, marriage, education, seniority, shift work and economic situation.

Table 1: Demographic variable data of the sample population

	n	%		n	%
Age			Work units		
20–24	8	5.8	Emergency	6	4.3
25–29	41	29.7	Outpatient	11	8.0
30–34	25	18.1	Acute ward	62	44.9
35–39	30	21.7	Rehabilitation ward	26	18.8
40–45	24	17.4	Day-patient service	9	6.5
46 and over	10	7.2	Others	24	17.4
Gender			Shifts		
Male	25	18.1	Non-shift	35	25.4
Female	113	81.9	Permanent shift	39	28.3
Marital status			Non-permanent shift	64	46.3
Married	71	51.4	Education		
Unmarried	61	44.2	Institute	6	4.3
Divorced	5	3.6	University	90	65.2
Cohabiting	0	0.0	Junior college degree	41	29.7
Widowed	1	0.7	High school	1	0.7
Others	0	0.0	Junior school and below	0	0.0
With child			Years of service		
Y	69	50.0	6 m	18	13.0
N	69	50.0	6 m to 1 y	13	9.4
Title			1–2 y	8	5.8
Nurse	112	81.2	2–3 y	5	3.6
Head nurse	11	8.0	3–4 y	12	8.7
Other	15	10.9	More than 4 y	82	59.4

Note: Total sample n=138

There were 18.1% males and 81.9% females of these, 29.7% subjects were between 25 and 29 years old. The average age was 30 to 34 years old. 51.4% subjects were married and half of the married staff had children. Of the subjects, 81.2% were “nurses”, 44.9% worked in emergency wards and 18.8% worked in rehabilitation wards. A total of 59.4% subjects had worked in senior positions for over four years, and most of these senior staff members were 35 to 39 years old. In terms of shift work, 25.4% fell into the category non-shifts, 28.3% permanent shift work and 46.3% worked non-permanent shifts. In our study, 74.6% of the clinical nursing staff worked shifts, which suggests that shift work is used widely in clinical nursing.

Table 2 shows the overall heart rate variability and overall activity of the autonomic nervous system, as well as the parasympathetic and sympathetic activity of the subjects.

Table 2: The heart rate variability (HRV) of the clinical nursing staff

Test items and result	Overall		Non-shift		Permanent shift		Non-permanent shift	
	Number of times	Percentage	Number of times	Percentage	Number of times	Percentage	Number of times	Percentage
Overall HRV								
Normal	105	6.34%	55	13.10%	40	8.55%	10	1.30%
Abnormal	1,551	93.66%	365	86.90%	428	91.45%	758	98.70%
Overall activity of the autonomic nervous system								
Normal	1,030	62.20%	281	66.90%	310	66.24%	439	57.16%
Abnormal	626	37.80%	139	33.10%	158	33.76%	329	42.84%
Parasympathetic activity								
Normal	803	48.49%	242	57.62%	255	54.49%	306	39.84%
Abnormal	853	51.51%	178	42.38%	213	45.51%	462	60.16%
Sympathetic activity								
Normal	837	50.54%	215	51.19%	242	51.71%	380	49.48%
Abnormal	819	49.46%	205	48.81%	226	48.29%	388	50.52%
Total	1,656	100.00%	420	100.00%	468	100.00%	768	100.00%

Note: Among the 138 clinical nursing staff in the sample, 35 did non-shift work, 39 did permanent-shift work and 64 did non-permanent shift work. Each subject was assessed monthly from January to December 2010. This culminated in a total of 1,656 observations.

We found that 95% of the subjects' overall heart rate variability was exceptional with all the staff with non-permanent shift work showing exceptional overall heart rate variability. Fifty percent of the subjects also showed exceptional parasympathetic and sympathetic activity, while 38.41% displayed exceptional overall activity of the autonomic nervous system. Compared to the subjects with non-shift work and permanent shift work, the clinical nursing staff with non-permanent shift work had a higher ratio of exceptional results. These three indices infer that the clinical nursing staff were not healthy and were at risk of cardiac death. In particular, the subjects with non-permanent shift work displayed the worst performance in these indices. Our results suggest that clinical nursing staff suffer a high risk of cardiac death and shift work may be an important factor in the deterioration of the health of clinical nursing staff.

When we used a binary logistic regression model to estimate the effects of shift work on overall heart rate variability and overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity, we set dummy variables, D_P and D_{NP}, to proxy represent permanent shift work and non-permanent shift work, respectively. Further, we set the cross term of D_P and D_{NP} with other control variables to control the marginal effect. The results are in Table 3.

Table 3: The effect of shift work on the probability of an abnormality in clinical nursing staff's heart rate variance (HRV)

	Overall HRV			Overall activity of the autonomic nervous system		
	Non-shift	Permanent shift	Non-permanent shift	Non-shift	Permanent shift	Non-permanent shift
Constant	0.564**			0.244**		
D_P		0.019			-0.008	
D_{NP}			0.042**			0.063**
Age	0.069**			-0.011*		
Marital status	0.085			0.037*		
Presence/absence of child	0.155**			0.065**		
Education	0.021			-0.018		
Years of service	0.015**			0.076**		
D_P×*Age*		0.002			0.001	
D_P×*Marital status*		0.003			-0.002	
D_P×*Presence/absence of child*		0.012*			0.003	
D_P×*Education*		0.001			-0.000	
D_P×*Years of service*		0.002			0.003	
D_{NP}×*Age*			0.032**			0.003*
D_{NP}×*Marital status*			0.027			0.020*
D_{NP}×*Presence/absence of child*			0.036**			0.057**
D_{NP}×*Education*			0.005*			-0.008
D_{NP}×*Years of service*			0.001*			0.084**
Likelihood			-955.305**			-984.761**
Adj/Pseudo R^2			0.041			0.043
Number of samples			1,656			1,656

*Notes: ** and * indicate significance at levels of 1%, and 5%, respectively.*

Table 3. The effect of shift work on the probability of an abnormality in clinical nursing staff's heart rate variance (HRV) (continuation)

	Parasympathetic activity			Sympathetic activity		
	Non-shift	Permanent shift	Non-permanent shift	Non-shift	Permanent shift	Non-permanent shift
Constant	0.161**			0.309**		
D_P		0.028			-0.006	
D_{NP}			0.086**			-0.011
Age	0.059**			0.066**		
Marital status	0.035			0.043*		
Presence/absence of child	0.077**			0.102*		
Education	0.016			0.019		
Years of service	0.082**			0.155**		
D_P×*Age*		0.006*			-0.005	
D_P×*Marital status*		0.004			0.002	
D_P×*Presence/absence of child*		0.004			0.007	
D_P×*Education*		0.002			0.001	
D_P×*Years of service*		0.005*			0.006	
D_{NP}×*Age*			0.015**			-0.004
D_{NP}×*Marital status*			0.012*			0.002
D_{NP}×*Presence/absence of child*			0.049**			0.002
D_{NP}×*Education*			0.017			0.002
D_{NP}×*Years of service*			0.038**			0.007
Likelihood			-975.316**			-923.154**
Adj/Pseudo R^2			0.047			0.036
Number of samples			1,656			1,656

*Notes: ** and * indicate significance at levels of 1%, and 5%, respectively.*

D_P had no significant effect on overall heart rate variability or overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity. When sympathetic activity was excluded, D_{NP} had a significantly detrimental effect on the overall activity of the autonomic nervous system and parasympathetic activity, and there were all significance at levels of 1%. In the part of cross term, D_P only exacerbated the marginal effect of having children on overall heart rate variability, and enhanced the marginal negative effect of age and seniority on parasympathetic activity, with a 5% significance level. D_{NP} on the other hand increased the marginal negative effect of age, having children with a 1% significance level, education and seniority with a 5% significance level on overall heart rate variability; it exacerbated the marginal effect of having children with a 1% significance level, marriage and seniority age with a 5% significance level on the abnormal overall activity of the autonomic nervous system; and it amplified the marginal effect of age, marriage ,having children, and seniority on abnormal parasympathetic activity. Most of these results showed a 1% significance level.

4 Discussion

Our empirical results showed that the effect of permanent shift work on each HRV index is insignificant while the effect of non-permanent shift work on these HRV indices, excluding sympathetic activity, was significant at 1%. In terms of the marginal effects, non-permanent shift work significantly influenced more factors than permanent shift work, achieving a significance level of 1%. The results demonstrate that the effects of non-shift work and permanent shift work are not different; however, non-permanent shift work significantly exacerbates the negative effects of age, family and work on the health of clinical nursing staff. Obviously, non-permanent shift work damages nursing staff's health significantly more than non-shift work and permanent shift work.

5 Conclusion

In this study, we assessed the effects of different types of shift work on clinical nursing staff's overall heart rate variability and overall activity of the autonomic nervous system, including parasympathetic and sympathetic activity, in order to investigate the relationship between shift work and the health of clinical nursing staff. The results show that there is no significant difference between the effect of non-shift work and permanent shift work on nursing staff's health indices. However, the health condition of subjects with non-permanent shift work was significantly poorer. In addition, non-permanent shift work enhanced the negative effects of increasing age, family and cumulative tiredness on clinical nursing staff's health. Because the disadvantages of non-permanent shift work in our study were more serious than those of non-shift and permanent shift work, we

recommend that non-permanent shift work be avoided, even under circumstances when nursing resources are lacking. In many medical institutions, non-permanent shift work is used to maximise the utilization of medical equipment. However, the negative effects of non-permanent shift work on clinical nursing staff's health should be taken into consideration. The cost of training clinical nursing staff is high. If clinical nursing staff are continuously subjected to working conditions that undermine their health, the quality of medical services might deteriorate, and clinical nursing staff will feel that they have no option but to resign from their jobs. Therefore, if shift work is unavoidable for clinical nursing staff, permanent shift work should be considered rather than non-permanent shift work.

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Conflict of Interest
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Appendix

We adapted a binary logistic regression model to test our arguments. We set a dummy variable, HI_i, to represent the clinical nursing staff's health records. HI_i equalled 1 if the record was exceptional, otherwise 0.

$$P_i = E(HI_i) = f(\beta' x_i) = \frac{1}{1+e^{-\beta' x_i}} = \frac{e^{\beta' x_i}}{1+\beta' x_i} \quad (1)$$

where P_i is the cumulative probability of an exceptional event and x_i is the independent variable to explain the probability of exception. Eq. (1) is a monotonic function. This function can thus be transformed into a linear regression pattern using transformation processes after obtaining the logarithm in Eq. (2):

$$ln\left(\frac{P_i}{1-P_i}\right) = \beta' x_i \quad (2)$$