The Relationship Between Autonomic Nervous System Activities and Work-life Balance of Nurses Working Two Shifts at a University Hospital

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大学病院で二交代制勤務をする看護師の自律神経活動とワーク・ライフ・バランスとの関連

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Abstract

Aim：The purpose of this study was to determine the relationship between autonomic nervous system activities and work-life balance（WLB）of nurses working two shifts at a university hospital.

Methods：A total of 168 nurses（mean age 30.8 ± 8.35 years）working two shifts at University Hospital A were included in this study. Physical stress index（PSI）, sympathetic activity index（low frequency; LF）, parasympathetic activity index（high frequency; HF）, and sympathetic and parasympathetic balance index（LF/HF）were measured after work using autonomic nervous system activity measures; the WLB index survey was conducted. For autonomic activity indices, a t-test was conducted on two groups: day shift and night shift. In addition, a group comparison was made between the standard and nonstandard groups. The relationship between WLB indices and the autonomic nervous system activity indices were examined by analysis of variance and multiple regression analysis.

Results：There were significant differences in HF, LF/HF, and PSI after the day and night shifts. In addition, the LF and PSI for both shifts were higher in the non-standard group. The standard group scored higher in the following WLB indices:“Work Discretion,”“Personnel Management,”“Childcare and Elderly Care,”and“Personal Development.”Correlations were found between

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the WLB indicators“Work Discretion,”“Personnel Management,”“Childcare and Elderly Care,”“Self-Development,”and“Social Activities”and the autonomic indices LF, HF, and PSI after night work.

Conclusion： In terms of the percentage of standard and nonstandard groups in the autonomic index, the percentage of LF on the day and night shifts, and percentage of non-standard groups in the PSI were higher, suggesting that the nurses were in a state of physical fatigue and stress regardless of their work schedule. Thus, it is necessary to examine improvements in individual and organizational factors that affect nurses' WLB in the workplace as a whole. Studies should examine the improvement in individual and organizational factors that affect the WLB of nurses in the entire workplace.

Keywords： two-shift work, nurses, work-life balance, autonomic nervous system activity

要旨

【目的】大学病院で二交代制勤務をする看護師の自律神経活動とワーク・ライフ・バランス（以下 WLB）との関連を明らかにする．

【方法】対象は A 大学病院で二交代制勤務をする看護師 168 名．（平均年齢 30.8 ± 8.35 歳）．自律神経活動計測器を用いて身体的疲労指標（PSI），交感神経活動指標（LF），副交感神経活動指標（HF），交感・副交感神経バランス指標（LF/HF）を勤務後測定し WLB 指標調査を行った．自律神経活動指標は，日勤勤務と夜勤勤務の 2 群とし t 検定を行った．また，標準群と非標準群の群間比較を行った．WLB 指標と自律神経活動指標との関連は分散分析，重回帰分析を行い検証した．

【結果】日勤後と夜勤後の HF，LF/HF，PSI に有意差を認めた．また両勤務の LF，PSI の非標準群の割合が高かった．WLB 指標の「仕事の裁量」「人事管理」「育児と介護」「自己啓発」「社会活動」と主に夜間勤務後の自律神経指標 LF，HF，PSI との間に相関関係を認めた．

【結論】自律神経指標の標準群，非標準群の割合において，日勤と夜勤の LF，PSI の非標準群の割合が高く，勤務帯を問わず身体的疲労，ストレスの状態であると推測された職場全体で看護師の WLB に影響する個人要因，組織要因の改善について検討することが求められる．

キーワード：二交代制勤務，看護師，ワーク・ライフ・バランス，自律神経活動

1 Introduction

Nurses are nationally qualified medical professionals, and those placed in hospitals either work at night or in shifts. Shift work disrupts the circadian rhythm and strains the body. Yonesawa 1 et al.[1] found that physical symptoms perceived by nurses were mainly sympathetic symptoms, such as stiff shoulders, back pain, headache, cold hands and feet, and constipation, and more than 70% experienced back pain and headaches. Yoshioka et al.[2] noted that the median value was significantly higher when nurses were subjected to a higher workload, supporting an association between occupational stress and physical responses. In addition, Yonesawa et al.[3] found that nurses had the lowest self-esteem and highest depression by occupation, according to a survey by the Health Counseling Study Group. They stated that these symptoms are thought to result from stress-induced sympathetic nervous system tension, constriction of blood vessels, and blood abnormalities, suggesting that nurses are constantly placed in an environment of strong tension. Dana et al.[4] found that shift work was associated with an increased risk of sleep disturbances, cardiovascular problems, and psychological disorders, which may negatively affect work-life balance (WLB).

Thus, the impact of occupational stress on nurses' physical and mental aspects is evident, and it is necessary to establish an environment in which nurses can rest and refresh themselves to reduce work-related fatigue and stress.

This study aimed to determine the relationship between autonomic nerve indices, objective stress measures, and the WLB indices for nursing professionals to respond flexibly to their life events and continue to work.

2 Methods

2.1 Definition of terms

Autonomic nervous system activity is defined as the physiological response of sympathetic and parasympathetic nervous systems to stimuli.

Work-life balance is a state in which a person can engage in a variety of activities, such as work, family life, community life, and personal development, in a balance that they desire.

2.2 Participants

A total of 168 nurses working two shifts at A University Hospital were included in the study, including 149 women (88.7%) and 19 men (11.3%). Individuals with cardiac diseases such as arrhythmia were excluded. Since a study by Murase et al.[5] showed that autonomic nervous system activity was not associated with sex differences in heart rate, statistical processing was performed by combining men and women.

2.3 Survey and measurement period

The survey and measurement period was from October to December 2020.

2.4 Implementation method

The participants underwent autonomic function measurements and completed self-administered questionnaires.

2.4.1 Autonomic function measurement

Autonomic nervous function was measured individually in a private room outside the workward at a room temperature of 25-26 ℃, according to the subject's work schedule. Autonomic nervous function

was measured twice in total: at the end of the day and during night shifts. The patient was placed in a sitting position, and a sensor was attached to the left third finger 2 minutes 30 seconds. The TAS 9 VIEW（YKC）measurement instrument was used in this study to evaluate autonomic function by measuring acceleration pulse waves from the fingertip. Among the heart rate variability analyses, frequency domain analysis was used to determine the specific frequency components inherent in the heart rate variability using the fast Fourier transform method with the R-R interval; the low-frequency（low frequency: 0.04-0.15 Hz: hereinafter LF）and high-frequency components（high frequency: 0.15-0.4 Hz: hereinafter HF）were calculated to analyze LH and HF. Logarithmic values were used in this study.

2.4.2　Content of the questionnaire survey

We asked the participants to fill out a self-administered questionnaire, place it in an envelope, and submit it in a collection box.

The attributes included age, gender, overtime hours, rest during work, single or married, and family（childcare, elderly case）.

The Work-Life Balance（WLB）Index is a scale developed by the Gakushuin University[6] Research Institute of Economics and Management in 2011, consisting of 23 items in the "external conditions（workplace environment）" and 19 items in the "personal WLB index." The responses were scored on a four-point scale（4 = strongly agree, 3 = somewhat agree, 2 = somewhat disagree, and 1 = strongly disagree）.

2.5　Method of analysis

To assess autonomic activity indices, a *t*-test was conducted for two groups: day and night shifts. In addition, a group comparison was performed between the standard and nonstandard groups for the autonomic index. Analysis of variance and multiple regression analysis were used to examine the relationship between the WLB indices and autonomic activity indices. Logarithms were used for the autonomic indices, and the significance level was set at 5 %.

2.6　Ethical considerations

The head nurse and research collaborators at a research collaborating facility were asked to cooperate verbally and in writing, in the study. Ethical considerations, such as the research purpose, method, timing, and assurance of personal information, were described in the research cooperation request document, and consent for research cooperation was obtained. The data and questionnaires in this study were managed in a locked storage area to prevent the leakage of personal information. This study was approved by the Research Ethics Committee of Himeji University School of Nursing（Approval No. 2020-02）. There was no conflict of interest.

3　Results

3.1　Overview of the participants

A total of 192 nurses underwent autonomic function measurements and completed the questionnaires. of them, 168 who responded to all the questionnaires with a confidence level（CF）of 96% or higher for autonomic function measurements were included in the study（valid response rate: 87.5%）.

3.1.1　Age

The average age of the respondents was 30.8 ± 8.35 years, ranging from their 20s to 50s: 92（54.8%）were 22-29 years old, 52（31.0%）were 30-39 years old, 16

(9.5%) were 40-49 years old, and 8 (4.8%) were 50-59 years old.

3.1.2 Status of taking breaks during work

Among the respondents being able to take breaks during work as prescribed, 146 (86.9%) were able, while 19 (11.3%) were unable to take breaks during work.

3.1.3 Overtime hours per week

The respondents answered the following: 4 (2.4%), "No overtime"; 115 (68.5%), "1-5 hours"; 17 (10.1%), "6-10 hours"; 2 (1.2%), "11-20 hours"; 5 (3.0%), "21 hours or more"; and 25 (14.9%) did not answer.

3.1.4 Being single or married

There were 128 (76.2%) single (including divorced) and 38 (22.6%) married participants.

3.1.5 Family relationships (childcare and elderly care)

With regard to the burden of raising children, the respondents answered the following:124 (73.8%) respondents answered "no burden at all," 19 (11.3%) answered "some burden," 10 (6.0%) answered "very much burden," and 15 (8.9%) did not respond. 146 (86.9%) respondents answered "no burden at all," 7 (4.2%) answered "some burden," and 15 (8.9%) did not respond.

3.2 Relationship between attributes and autonomic indices

There were no significant differences between unmarried, married, and family relationships (childcare and elderly care) and autonomic indices.

3.3 Comparison of autonomic indices between two shifts

Table 1 shows a comparison of the autonomic indices between the two shifts, and Table 2 shows the reference range of the autonomic indices.

3.3.1 LF

The mean LF, an index of the sympathetic nervous system, was 5.30 ± 0.95 after the day shift and 5.23 ±1.18 after the night shift, and no significant difference was found between the shifts. These results were below the reference range for both the shifts.

3.3.2 HF

The mean HF, an index of the parasympathetic nervous system, was 5.58 ± 1.13 after the day shift and 5.80 ± 1.06 after the night shift, and the difference between the two shifts was significant. These results were within the reference range.

3.3.3 LF/HF

The mean LF/HF, an index of the overall balance between the sympathetic and parasympathetic nervous systems, was 0.97 ± 0.18 after the day shift and 0.91 ± 0.18 after the night shift; the difference between the two shifts was significant. These results were within the reference range.

3.3.4 PSI

The PSI, which is an index of physical stress and fatigability level, indicates that the higher the value, the more overworked the person is. The mean PSI was 5.27 ± 0.58 after the day shift and 5.11 ± 0.63 after the night shift, and the difference between the two shifts was significant. These values were above the reference range.

3.3.5 SDNN

The mean SDNN, an index of physical fitness, was 45.66 ± 15.25 after the day shift and 52.63 ± 20.72 after the night shift, and the difference between the two shifts was not significant. These results were within the reference range.

Table 1. Comparison of Autnomic Indices between Day and Night Shifts

Work hours	PSI		SDNN	LnLF	LnHF		Ln（LF/HF）	
After day shift	6.27 ± 0.58	＊	45.66 ± 15.25	5.30 ± 0.94	5.58 ± 1.13	＊	0.97 ± 0.18	＊
After night shift	5.11 ± 0.63		52.63 ± 20.72	5.23 ± 1.18	5.80 ± 1.06		0.91 ± 0.18	

t 検定　＊ $p < .05$　＊＊ $p < .01$

Table 2. Reference Ranges for Autonomic Nerve Indices

Autonomic index	PSI	SDNN	LnLF	LnHF	Ln（LF/HF）
Reference range	4.0-5.0	30 or more	5.50-7.90	4.19-7.23	0.52-2.32

How to interpret the measurements of TAS9 VIEW,YKC, 2019

3.4 Comparison of autonomic indices between the standard and nonstandard groups

The proportions of the standard and nonstandard groups for each autonomic index are listed in Table 3. The nonstandard groups for LF and HF were defined as those with autonomic nervous system activity below the standard group, and the nonstandard group for PSI was defined as having individuals with physical fatigue above the standard group（overworked group）. PSI and LF were two indices with a greater proportion in the nonstandard group. Regarding PSI, 60（35.7%）participants were in the standard group and 108（64.3%）in the nonstandard group after the day shift; 77（45.8%）were in the standard group and 91（54.2%）in the nonstandard group after the night shift. Regarding LF, 38（22.6）were in the standard group and 130（77.4%）in the nonstandard group after the day shift; 38（22.6%）were in the standard group and 130（77.4%）in the nonstandard group after the night shift. The Wilcoxon signed-rank test between the day and night shifts in the standard and nonstandard groups for each autonomic index showed significant differences in PSI and HF between the day and night shifts in the nonstandard group.

3.5 Relationship between the autonomic index and WLB index

Table 3 shows the correlations between the autonomic and WLB indices for the two shifts. After the day shift,“personnel management”and ln（HF）were weakly correlated at $r = .208$（$p = .007$）. After the night shift, the correlation between“management policy”and ln（LF）was $r = .238$（$p = .002$）;“work discretion”and PSI was $r = -.219$（$p = .005$）;“work discretion”and ln（LF）was $r = .250$（$p = .001$）;“work discretion”and ln（HF）was $r = .209$（$p = .007$）;“personnel management”and ln（LF）was $r = .262$

Table 3. Percentage of Standard and Nonstandard Groups for Each Autonomic Nerve Index

Group	PSI		SDNN		LnLF		LnHF		Ln（LF/HF）	
	after day shift	after night shift	after day shift	after night shift	after day shift	after night shift	after day shift	after night shift	after day shift	after night shift
Standard Groups	60(35.7)	77(45.8)	136(81.0)	140(83.3)	38(22.6)	38(22.6)	137(81.5)	151(89.9)	167(99.4)	165(98.2)
Nonstandard Groups	108(64.3)	91(54.2)	32(19.0)	28(16.7)	130(77.4)	130(77.4)	31(18.5)	17(10.1)	1(0.6)	3(1.8)
		＊						＊		

＊ $p < .05$　Figures in parentheses indicate the percentage of nurses who fall in the group.

Table 4. Correlation between Autonamic Nerve Activity Index and LLB Index

Autonamic Nerve / WLB index	PSI		LnLF		LnHF	
	after day shift	after night shift	after day shift	after night shift	after day shift	after night shift
Management policy	-0.087	-0.147	0.171	0.238**	0.166	0.163
Work discretion	-0.091	-.219**	0.061	0.250**	0.086	0.209**
Personnel Management	-0.164	-0.147	0.181	0.262**	0.208**	0.196*
Childcare and elderly care	-0.103	-0.18	0.037	0.226**	0.124	0.212**
Self-development	-0.119	-0.131	0.104	0.213**	0.104	0.161
Social Activities	-0.163	-0.118	0.072	0.148	0.137	0.214**

* $p < .05$ ** $p < .01$

Table 5. WLB Indices Affecting Autonomic Indices (Multiple Regressin Analysis)

Dependent variable	PSI after night shift	
Explanatory variable	β	t value
Management policy	-0.066	-0.643
Work discretion	-0.192*	-2.076 *
Personnel Management	0.004	0.034
Adjusted R^2	0.034 *	
F value	2.927 *	

* $p < .05$ ** $p < .01$

Table 6. WLB index mean score

WLB index	mean point
Management policy	2.36 ± 0.67
Work discretion	2.10 ± 0.53
Personnel Management	2.49 ± 0.58
Childcare and elderly care	2.42 ± 0.97
Self-development	2.27 ± 0.76
Social Activities	1.85 ± 0.77
General and Work	2.47 ± 0.77
General and Life	2.68 ± 0.79
General	2.41 ± 0.81

($p = .001$); "childcare and elderly care" and ln (LF) was $r = .226$ ($p = .003$); "childcare and elderly care" and ln (HF) was $r = .212$ ($p = .006$); "self-development" and ln (LF) was $r = .213$ ($p = .006$); and "social activity" and ln (HF) was $r = .214$ ($p = .006$), all of which showed a weak correlation.

Table 4 shows the WLB indices that affected the autonomic indices. Multiple regression analysis was performed using the WLB indices that were correlated with autonomic indices as the explanatory variables, and the significant independent variable was "work discretion" ($R^2 = .034$, $\beta = -.192$, $p = .039$) for the dependent variable, PSI.

The WLB index scores are shown in Table 5. The score for "in general, I am satisfied with my WLB" (hereinafter referred to as "General") was 2.41 ± 0.81, that for "in general, I am satisfied with my life outside of work" (hereafter referred to as "Life and general") was 2.68 ± 0.79, and that for "overall, I am satisfied with my current job" (hereafter referred to as "Work and general") was 2.47 ± 0.77.

4 Discussion

4.1 Relationship between autonomic nervous system activity and shifts

There were significant differences between the two shifts in the autonomic indices PSI, HF, and LF/HF, and the proportion of the nonstandard group was significantly higher during the day shift, indicating that fatigue and stress were stronger during the day shift than during night shift. However, the mean PSI, a physical fatigue indicator, was above the cutoff value of the reference range for both shifts, suggesting that both shifts were physically fatiguing. The night shift duration is as long as 16 hours, but a two-

hour rest period is available and an interval between shifts is ensured. However, in the day shift, although there is one hour of rest time, there are tasks that are concentrated during the day, such as dealing with patients before and after examinations and surgeries, and accepting inpatients, and they have to move around to practice nursing during the shift, including self-care. These facts may account for the fact that physical fatigue was higher after the day shift than after the night shift.

HF, an index of the parasympathetic nervous system, was significantly higher in the night shift, suggesting that chronic and mental stress were lower in the night shift than in the day shift. However, in both shifts, the mean values were within the reference range, and the proportion of the nonstandard group was small, suggesting that chronic stress was less common. LF/HF denotes the overall balance of the sympathetic and parasympathetic nervous systems, and a significant difference in HF may have affected it. The mean LF/HF values were within the reference range, and the balance was not bad.

Naka et al.[7] found that sudden and short-lived emotional stress only results in a decrease in sympathetic function and a relative decrease in parasympathetic function. However, when anxiety and excitement persist for a long time, both the sympathetic and parasympathetic nervous systems simultaneously increase in function. In this study, was within the normal range, and the mean LF/HF ratio, a sympathetic and parasympathetic balance index, was also within the reference range, suggesting that the participants did not suffer from chronic stress. However, the mean HF and LF/HF ratio were closer to the non-reference range after the day shift, suggesting that if stress induced by day shifts persists chronically as acute stress, it will have an impact on the sympathetic nervous system. LF is a sympathetic nerve index that evaluates the state of acute stress associated with low energy due to fatigue and other factors. The results did not show any significant differences between the shifts, but the mean LF was below the reference range after both shifts. The percentage of the nonstandard group was as high as 77.4% in both the day and night shifts, suggesting a high level of stress in both shifts.

Our previous study[8] showed that nurses at university hospitals suffer from a high level of physical fatigue in both day and night shifts and are under acute stress. Since university hospitals are responsible for advanced medical care and the level of medical care provided to hospitalized patients is high, they inevitably require a high level of knowledge and skills in nursing care.

In recent years, there have been many elderly patients, and it is necessary to respond to their needs to promote independence according to their needs, indicating that the workload is very busy.

4.2 Relationship between autonomic activity and WLB indices

“Management policy” was weakly correlated with LF after the night shift, and “work discretion” was weakly correlated with PSI, LF, and HF after the night shift. “Management policy” refers to the basic policy of the organization, and “work discretion” refers to the ability to decide work procedures by oneself. “Work discretion” was correlated with post-night shifts, suggesting that the participants could exercise more discretion in their work during the night shift than during the day shift. During the day shift, nurses have

to carry out complex treatment plans such as surgeries, examinations, and treatments scheduled for the day, deal with hospitalizations and discharges, and provide daily nursing care within a limited timeframe. Thus, priorities are considered, but workload is overcrowded and heavy enough to not allow for work discretion. However, fewer nurses work during the night shift, and each nurse is in charge of more patients as well as patients from other teams that they are not in charge of during the day shift, so the responsibility is heavier and the tension is higher. However, compared with the day shift, the workload is not overcrowded, and nurses can adjust their duties at their own discretion, such as taking turns during the 16-hour shift to ensure rest and a proper implementation of treatment plans. We believe that there are many situations in which nurses can exercise practical nursing skills and decision-making abilities during the night shift.

"Personnel management" showed a correlation with LF after the night shift and HF after the day shift. Personnel management represents the characteristics of human resource management conducted by hospitals and encompasses placement, evaluation, salary, and skills development. Since the night shift requires managing the entire ward with a small number of people, the staffing system takes into account the nurses' skills and experience in responding to emergencies. However, a night shift is highly stressful, even for experienced nurses, and nurses work together to do their best for as long as 16 hours. Therefore, the sympathetic nervous system is highly active, and after the shift, energy levels drop, leading to a state of acute stress. Kato et al.[9] observed that workload and staffing affect the ability to take adequate rest, suggesting that it is important to ensure that nurses take rest during and after work to prevent stressful situations from becoming the norm.

"Childcare and elderly care" were correlated with LF and HF after night shifts. Nurses work two shifts while doing domestic work with the help of their husbands and parents. However, compared to single nurses, they need more time and effort to spend on childcare and elderly care, and when they are away at night for a 16-hour night shift, they go to work so that their families do not suffer from poverty. This makes it difficult for them to get enough rest, and we speculate that prolonged activity of the sympathetic nervous system contributes to their energy decline after the night shift. Kanezaki et al.[10] reported that only about 15% of those with infants and schoolchildren were exempted from night shifts and used shorter working hours for childcare, suggesting that working two shifts is difficult for nurses of childrearing age in terms of balancing work and life. We believe that allowing sufficient time for life events such as marriage, childbirth, and childcare will enable nurses to have specialized knowledge, skills, and attitudes to provide high-quality nursing care. To realize this, we believe it is necessary to set flexible work hours according to the timing of life events and have a better understanding of work in the workplace and at home.

"Self-development" was correlated with LF after the night shift. Night shifts were influenced by job discretion, and PSI resulted in lower physical fatigue than day shifts. Many nurses employed in university hospitals have goals for their career improvement and strive for self-improvement. Although sympathetic activity increases after the night shift, the intervals between shifts make it easier for them to take time for self-development and implement their career plans.

Kato et al.[11] noted that career planning may have the greatest impact on WLB, and we believe that it is important for organizations to provide career support for individual nurses.

"Social activity" was weakly correlated with HF after a night shift. Although it is physically difficult for nurses to participate in social activities of community associations and PTA, in reality, they are required to do so regardless of their work content and working style. We speculate that they cannot recover from fatigue due to a lack of rest time, which causes a decrease in parasympathetic activity, leading to chronic stress. While fulfilling our roles as members of society and valuing relationships in the local community, we should give top priority to securing time for nurses to recover from the fatigue and stress caused by work.

Multiple regression analysis showed that work discretion was a WLB index that affected PSI during night shifts. Kawamura et al.[12] noted that work environment indices, including（1）management policy,（2）work management, and（3）personnel management, as well as（4）work and life evaluation, were strongly associated with burnout, and when these factors are met, they may help prevent burnout. Work discretion is an item included in work management, and university hospitals providing advanced medical care are thought to maintain the quality of nursing care while adopting various regulations regarding nursing practice and methods unique to wards. However, work discretion, that is, the ability to determine one's own work procedures, can be considered a trigger to increase work efficiency and decrease physical fatigue.

Comparing the mean WLB indicator scores in the present results with the JUKU standard（results of a survey conducted by the WLB School and the Gakushuin University Research Institute of Economics and Management Research on nine volunteer companies in 2007）, although there was not much difference in the "General" score, it is necessary to take measures to improve job and life satisfaction.

Owing to the limited number of facilities in our study, the generalizability of our study results is limited. In the future, we would like to expand the scale of the survey and aim for generalization as well as make efforts to promote WLB among nurses.

5　Conclusion

The comparison of autonomic indices after day and night shifts in nurses working two shifts at university hospitals showed significant differences in HF, LF/HF, and PSI. As for the proportion of the standard and nonstandard groups in each autonomic index, the proportion of the nonstandard group in LF and PSI was higher in both shifts than that in the non-standard group, suggesting that the nurses were under physical fatigue and stress regardless of their work schedules. A correlation was found between WLB indices, such as "work discretion," "management," "childcare and elderly care," "self-development," "social activity," and autonomic indices, such as LF, HF, and PSI, in nurses working two shifts at university hospitals, mainly after the night shift. We speculate that creating a system that values nurses' work will reduce the load on the autonomic system after night shifts.

University hospitals are facilities that provide advanced medical care, and by creating a work environment that is easy for frontline nurses who work two shifts, we believe that we can develop experienced and high-quality nurses. It is necessary for the whole

organization to examine the improvement in individual and organizational factors affecting the WLB of nurses.

Acknowledgements

We would like to express our sincere gratitude to all the nurses who cooperated in this study, as well as the head nurses of the ward and nursing department.

This research was supported by the JSPS Grant-in-Aid for Scientific Research.

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