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ORIGINAL

Workload, Fatigue, and Cognitive Performance in University Hospital Nurses: A Cross-Sectional Study

Carga De Trabajo, Fatiga Y Rendimiento Cognitivo En Enfermeras De Hospitales Universitarios: Un Estudio Transversal

Meilisa Rahmadani[1], L. Meily Kurniawidjaja[2], Maya Arlini Puspasari[3], Novita Dwi Istanti[4], Dewi Yunia Fitriani[5], Mariam Mulia Istiqomah[1], Desy Sulistiyorini[6], Robiana Modjo[2]

[1]Universitas Indonesia Hospital, Occupational Health and Safety Department. Depok, Indonesia.
[2]Universitas Indonesia, Faculty of Public Health, Occupational Health and Safety Department. Depok, Indonesia.
[3]Universitas Indonesia, Faculty of Engineering. Depok, Indonesia.
[4]Universitas Indonesia Hospital, Quality and Planning Department. Depok, Indonesia.
[5]Universitas Indonesia, Faculty of Medicine, Occupational & Environmental Health Research Center, IMERI. Jakarta, Indonesia.
[6]Universitas Indonesia Maju, Faculty of Health Science. Jakarta, Indonesia.

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Corresponding author: Robiana Modjo

ABSTRACT

Introduction: as the largest workforce in the healthcare industry, nurses are essential to maintaining patient safety. Personal and environmental factors, including high demands, irregular work hours, and large workloads, make nurses vulnerable to fatigue.
Method: the study involved 60 participants using several tools for data collection, including the NASA Task Load Index (NASA-TLX) to assess workload, the Swedish Occupational Fatigue Inventory (SOFI) to measured fatigue, heart rate variability (HRV) measurements to evaluated autonomic nervous system activity, electroencephalogram (EEG) analyzed for cognitive functions, and the Psychomotor Vigilance Test (PVT) to assessed cognitive performance.
Results: the findings revealed that the nurses experienced high subjective workloads, particularly related to mental, physical, and temporal demands. Fatigue, especially in terms of energy depletion and sleepiness, was significantly reported. HRV data indicated a shift toward parasympathetic dominance after each shift, while EEG results showed decreased theta and alpha wave activity, suggesting increased fatigue. The PVT results showed slower reaction times and more lapses in performance, especially after night shifts, indicating cognitive impairment due to fatigue.
Conclusions: these results highlight the considerable impact of high workloads, shift work, and fatigue on the health and performance of nurses. The study suggests that healthcare institutions should implement strategies to reduce workload, manage fatigue, and improve recovery to maintain optimal cognitive performance and overall well-being of nursing staff. These findings can inform policies aimed at improving working conditions and ensuring better care delivery in hospital settings.

Keywords: Occupational Fatigue; Health Personnel; Workload; Mental Fatigue.

RESUMEN

Introducción: como la fuerza laboral más numerosa del sector sanitario, las enfermeras son esenciales para garantizar la seguridad de los pacientes. Los factores personales y ambientales, como las altas exigencias,

los horarios irregulares y las grandes cargas de trabajo, hacen que las enfermeras sean vulnerables a la fatiga.
Método: en el estudio participaron 60 personas y se utilizaron varias herramientas para la recopilación de datos, entre ellas el Índice de Carga de Trabajo de la NASA (NASA-TLX) para evaluar la carga de trabajo, el Inventario Sueco de Fatiga Ocupacional (SOFI) para medir la fatiga, mediciones de la variabilidad del ritmo cardíaco (HRV) para evaluar la actividad del sistema nervioso autónomo, electroencefalogramas (EEG) para analizar las funciones cognitivas y la Prueba de Vigilancia Psicomotora (PVT) para evaluar el rendimiento cognitivo.
Resultados: los resultados revelaron que las enfermeras experimentaban una elevada carga de trabajo subjetiva, especialmente en lo que se refiere a las exigencias mentales, físicas y temporales. Se informó de un nivel significativo de fatiga, especialmente en términos de agotamiento energético y somnolencia. Los datos de la VFC indicaron un cambio hacia el predominio parasimpático después de cada turno, mientras que los resultados del EEG mostraron una disminución de la actividad de las ondas theta y alfa, lo que sugiere un aumento de la fatiga. Los resultados de la PVT mostraron tiempos de reacción más lentos y más lapsos en el rendimiento, especialmente después de los turnos de noche, lo que indica un deterioro cognitivo debido a la fatiga.
Conclusiones: estos resultados ponen de relieve el considerable impacto de las elevadas cargas de trabajo, los turnos y la fatiga en la salud y el rendimiento de las enfermeras. El estudio sugiere que las instituciones sanitarias deberían aplicar estrategias para reducir la carga de trabajo, gestionar la fatiga y mejorar la recuperación, con el fin de mantener un rendimiento cognitivo óptimo y el bienestar general del personal de enfermería. Estos hallazgos pueden servir de base para políticas destinadas a mejorar las condiciones de trabajo y garantizar una mejor prestación de la atención sanitaria en los entornos hospitalarios.

Palabras Clave: Fatiga Laboral; Personal Sanitario; Carga de Trabajo; Fatiga Mental.

INTRODUCTION

Fatigue is the feeling of mental or physical exhaustion that can result in deteriorating performance and is caused by chronically shortened sleep, acute sleep deprivation, night working, or high work intensity and reduced willingness to perform daily activities, even after resting.[1,2] Fatigue is defined in various ways, but the American Nursing Diagnosis Association describes it as a persistent, overwhelming exhaustion that reduces physical and cognitive ability and is not relieved by rest.[3]

Nurses, being the largest workforce in the healthcare sector, play a vital role in ensuring patient safety. Their responsibilities include identifying errors and near misses, noticing and reporting changes in patients' conditions, and providing high-quality care.[3] Nurses are prone to fatigue due to personal and environmental characteristics, such as heavy workloads, non-standard work schedules, and exposure to high demands.[4-6] Fatigue negatively impacts nursing performance, resulting in a higher number of medical errors, reduced patient safety, and an increased incidence of nurse injuries.[4] The concern surrounding nurse fatigue is associated with lower job satisfaction, higher burnout levels, and a greater likelihood of nurses intending to leave the profession.[7] Additionally, research has consistently shown that it is strongly associated with mental health challenges, including burnout, emotional exhaustion, and secondary traumatic stress.[8]

Hence, it is essential to assess this fatigue scientifically to enhance nurse health management and improve their quality of life, ultimately ensuring patient safety.[1,8] Although interest in nurse fatigue is growing, most studies rely on either subjective self-reports or objective physiological data, rarely integrating both. This limits a full understanding of the complex cognitive, physical, and emotional dimensions of fatigue. A more comprehensive approach is needed to develop effective interventions that support nurse well-being and patient care. Addressing this gap is essential for developing effective interventions that enhance nurse well-being, optimize job performance, and ultimately safeguard patient outcomes.

Therefore, this study aimed to assess the subjective workload, fatigue, physiological parameters, and cognitive performance of full-time nurses and nurse assistants using questionnaires such as NASA-TLX and SOFI with objective measurements like HRV, EEG, and PVT. This study seeks to provide a more comprehensive and accurate evaluation of nurse fatigue, ultimately contributing to improved nurse health management, quality of life, and patient safety.

METHOD

This study employs a clear and systematic approach ensure and validity of the findings. Below are the components of the methodology:

Research Type

This study used a quantitative approach with a cross-sectional survey design. A stratified random sampling recruited 60 full-time service nurses and nurse assistants from 4 department: Operatie Kamer (OK), Intensive Care Unit (ICU), Emergency Installation (IGD), Inpatient Unit. Those who agreed to participate in the study signed a written informed consent form and were subsequently enrolled.

Population and Sample

The study population included all nurses (400 people) from each unit (8 units) in X Hospital. The sample used the following criteria: (1) involving nurses who are actively working in Hospital X; (2) nurses in work units that have 3 shifts. Nurses who were under medication and not willing to be the object of research were excluded, and a sample of 60 nurse respondents divided into several units was determined.

Research Location

This study was performed at a university hospital in the suburban area of Jakarta, a culturally diverse area with a mix of urban and semi-urban populations, which provided a unique context for understanding the fatigue condition in nursing staff.

Instrumentation or Tools

Data were collected using several tools for data collection, including the NASA Task Load Index (NASA-TLX) to assess workload, the Swedish Occupational Fatigue Inventory (SOFI) to measured fatigue, heart rate variability (HRV) measurements to evaluated autonomic nervous system activity, electroencephalogram (EEG) analyzed for cognitive functions, and the Psychomotor Vigilance Test (PVT) to assessed cognitive performance. Below are the descriptions of each tool:

- Subjective workload measurement of participants: The NASA Task Load Index (NASA-TLX), a widely used tool for over two decades, assesses perceived mental workload across six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration.(3) This bipolar rating scale identifies the most critical contributor to workload based on the highest score among dimensions. Its reliability has been supported by test-retest studies, with Batisse and Bortolussi (1988) reporting a coefficient of 0,77.(10,11)
- Perceived fatigue measurement of participants: Fatigue levels were measured using the Swedish Occupational Fatigue Inventory (SOFI), developed to capture physical, cognitive, and psychosocial aspects of fatigue.(12,13) This 20-item self-report instrument is organized into five dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness.(12,14)
- Record of physiological parameters: Heart rate variability (HRV) was monitored using the Polar H10 chest strap sensor in conjunction with the Elite HRV app, which records RR-interval data. The data were further processed using the Kubios HRV Scientific software to generate comprehensive HRV metrics such as SDNN, RMSSD, and spectral power across VLF, LF, and HF frequency bands.(15)
- Assessment of cognitive performance: Cognitive function was assessed using EEG measurements focused on frontal brain regions associated with executive functions essential to nursing tasks. The Emotiv Insight headset recorded brainwave activity over a 5-minute session, with data analyzed through the EmotivPRO platform using band-pass filtering and Fast Fourier Transform (FFT) to classify signals by frequency. Results were presented as power spectral density (PSD) in decibels (dB).(16)
- Assessment of neurobehavioral performance: The Psychomotor Vigilance Task (PVT), specifically the PC-PVT software, evaluated attention and reaction time as indicators of neurobehavioral performance. Over a 3-minute session, participants responded to visual stimuli, with key outcomes including mean reaction time, number of lapses, 10 % fastest and slowest RTs, and false starts (RT < 100 ms).(11,17)

Data Collection Procedures

The data collection stage includes the collection of objective and subjective data was collected in October 2023. Objective data uses the Electroencephalogram (EEG) tool and is recorded using the EmotivPRO application, Psychomotor Vigilance Task (PVT), and heart rate variability (HRV) collected before and after work. While subjective data in the form of workload scores taken using the NASA Task Load Index (NASA-TLX) questionnaire and fatigue levels are measured using Swedish Occupational Fatigue Inventory (SOFI). Respondents were provided a consent form and instructions for completing the questionnaire.

Data Analysis

EEG recording data is processed into waveforms and power in the EmotivPRO application before being statistically tested using SPSS software, as well as HRV and PVT results. For subjective data, data obtained from the NASA-TLX and SOFI questionnaires were statistically tested using SPSS software. Quantitative and participants' demographic data were analyzed using descriptive statistics.

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Ethical Approval

This study was approved by the Health Research Ethics Committee of Universitas Indonesia University Hospital with Ethical Clearance No: S-083/KETLIT/RSUI/VI/2024. All participants provided informed consent prior to participating in the study. The confidentiality of all participants was strictly maintained throughout the research process.

RESULTS

From table 1, the data reveals that the majority of respondents are female (83,3 %) with an average age of 28,25 years. A concerning trend is that 93,3 % of respondents sleep less than 7 hours per day. Most of the respondents have more than 3 years of work experience (63,3 %) and work primarily as staff nurses (63,3 %). Additionally, the largest proportion of respondents is employed in the Inpatient unit (46,7 %).

Table 1. Demographic Characteristics And Work-Related Information of Participants

Quantitative variables	M ± SD	Min	Max
Age (years)	28,25 ± 2,191	25	34
Height (cm)	159,7 ± 7,55	148	185
Weight (kg)	61,91 ± 18,48	39	130
Quantitative variables		n	%
Gender	Female	50	83,3
	Male	10	16,7
Marital status	Single	45	75
	Married	15	25
Working experience	≥ 3 years	38	63,33
	< 3 years	22	36,67
Working Unit	Intensive Care Unit	16	26,7
	Emergency Department	9	15
	Operating Room	7	11,7
	Inpatient	28	46,7
Sleep quantity	<7 hours/day	56	93,3
	>7 hours/day	4	6,7
Commuting time	<20 minutes	31	51,7
	>20 minutes	29	48,3
Shift work	Morning	23	38,3
	Afternoon	20	33,3
	Night	17	28,3
Tenure	>3 years	38	63,3
	<3 years	22	36,7
Position	Staff nurses	38	63,3
	Primary nurses	15	25
	Associate nurses	7	11,7

Subjective Workload Measurement of Participants

The results of the NASA-TLX questionnaire (table 2) assessing the workload of nurses in a hospital reveal some key findings. The overall workload, as indicated by the total score, shows that the majority of nurses experience a high to very high workload, with 60 % of participants reporting very high workload (score range 80-100), and 37 % reporting high workload (score range 50-79). Only 3 % of the respondents reported a medium workload (score range 10-29), while no nurses fell into the low or somewhat high categories.

Table 2. Mean scores of mental workloads and its dimensions among nurses assessed by NASA-TLX

Indicator	M ± SD	Median	Min	Max
Mental Demand	161,50 ± 103,79	160,00	0,00	450,00
Physical Demand	183,50 ± 115,67	180,00	0,00	450,00

Temporal Demand	222,67 ± 109,25	210,00	0,00	500,00
Own Performance	179,83 ± 135,70	160,00	0,00	400,00
Effort	304 ± 144,45	320,00	0,00	500,00
Frustration	142,83 ± 145,51	95,00	0,00	500,00
Total Score	79,62 ± 13,60	83,67	36,67	100,00
Workload classification		**Score**	**n**	**%**
	Low	0-9	0	0
	Medium	10-29	2	3
	Somewhat high	30-39	0	0
	High	50-79	22	37
	Very high	80-100	36	60

Perceived Fatigue Measurement of Participants

The SOFI questionnaire results assessing fatigue among nurses reveal several key findings (table 3). The highest mean score was for Lack of Energy (4,547 ± 1,0544). Sleepiness also showed a notable mean of 3,747 (± 0,9969). In contrast, Lack of Motivation had a lower mean score of 2,903 (± 1,0650). Physical Exertion and Physical Discomfort were also present but with lower mean scores of 2,930 (± 0,7990) and 3,053 (± 1,1235).

Table 3. Perceived fatigue assessed by SOFI

Dimension	Min	Max	Mean	Std. Deviation	Kurtosis	
					Statistic	Std. Error
Lack of Energy	1,2	6,0	4,547	1,0544	0,911	0,608
Lack of Motivation	1,0	5,4	2,903	1,0650	-0,447	0,608
Sleepiness	1,2	5,8	3,747	,9969	0,249	0,608
Physical exertion	1,0	5,0	2,930	,7990	-0,168	0,608
Physical discomfort	1,0	5,4	3,053	1,1235	-0,562	0,608

Record of Physiological Parameters

The EEG measurements of fatigue in nurses across different shifts (table 4) reveal important trends in brain wave activity. For all shifts, there was a decrease in theta from 9,18 to 8,66 during the morning shift, from 8,72 to 8,34 in the afternoon, and from 9,30 to 8,49 during the night shift. Alpha waves also dropped across shifts, with a decrease from 6,46 to 5,87 in the morning, from 6,96 to 6,24 in the afternoon, and from 6,16 to 5,38 at night. Beta waves show, decrease in beta high across all shifts. Notably, the relative power ratios (RPR) of theta and alpha also decreased. The RPR of beta low and high remained more stable.

Table 4. Record of Physiological Parameters

Average power and relative power ratio (RPR) derived from EEG measurements								
Average	**Theta**	**Alpha**	**Beta Low**	**Beta High**	**RPR Theta**	**RPR Alpha**	**RPR Beta Low**	**RPR Beta High**
Morning shift								
Before	9,18	6,46	4,40	3,47	39,38	28,18	18,05	14,40
After	8,66	5,87	4,29	3,43	39,18	26,70	18,97	15,15
Afternoon shift								
Before	8,72	6,96	3,74	2,78	39,40	31,52	16,62	12,46
After	8,34	6,24	3,97	3,26	38,46	28,75	17,85	14,95
Night shift								
Before	9,30	6,16	4,38	3,23	40,53	26,10	19,14	14,23
After	8,49	5,38	4,14	2,97	41,11	25,64	19,42	13,82
The mean differences of HRV parameters by work shifts								
Average	**Mean RR (ms)**	**SDNN (ms)**	**Mean HR (bpm)**	**RMSSD (ms)**	**VLF (ms^2)**	**LF (ms^2)**	**HF (ms^2)**	**LF/HF**
Morning shift								
Before	731,50	34,19	82,91	36,33	68,14	360,10	512,89	1,05

After	745,25	30,65	81,36	30,94	59,36	329,23	520,02	0,90
Afternoon shift								
Before	687,85	29,93	88,18	26,65	51,25	413,43	609,05	1,45
After	786,33	35,90	77,33	35,69	85,41	560,50	689,05	1,32
Night shift								
Before	722,04	31,42	83,88	31,65	68,22	397,74	478,86	1,76
After	803,32	36,52	75,55	39,21	133,31	529,15	737,23	1,57

Heart rate and heart rate variability (HRV) parameters were measured before and after the experimental procedure across three shifts: morning, afternoon, and night (table 4). In the morning shift, before the shift, the mean RR interval was 731,50 ms, with a mean heart rate (HR) of 82,91 bpm and SDNN of 34,19 ms, reflecting a moderate level of HRV. After the shift, the mean RR increased to 745,25 ms. However, the HR decreased to 81,36 bpm, and SDNN decreased to 30,65 ms, which shows a reduction in HRV. The LF/HF ratio decreased from 1,05 to 0,90. For the afternoon shift, before the shift, the mean RR was 687,85 ms, with a higher HR of 88,18 bpm and SDNN of 29,93 ms. After the shift, the mean RR increased to 786,33 ms, with a decrease in HR (77,33 bpm) and an increase in SDNN (35,90 ms). The LF/HF ratio decreased from 1,45 to 1,32. In the night shift, before the shift, the mean RR was 722,04 ms, with an HR of 83,88 bpm and SDNN of 31,42 ms. After the shift, the mean RR increased significantly to 803,32 ms. HR decreased to 75,55 bpm, and SDNN increased to 36,52 ms, further confirming recovery. The LF/HF ratio slightly decreased from 1,76 to 1,57.

Sleepiness and alertness assessment using PVT

The results from the Psychomotor Vigilance Test (PVT) (table 5) revealed that reaction times (RT) increased significantly from before to after the shifts, with the morning shift showing an increase from 328,26 ms to 364,95 ms, the afternoon shift from 327,25 ms to 364,95 ms, and the night shift from 293,48 ms to 350,06 ms. The frequency of minor lapses in attention increased after the shifts, with the night shift exhibiting a particularly sharp rise from 0,65 to 3,65.

Table 5. Psychomotor Vigilance Task Test Outcome Measures in Different Work Shifts

Average Reaction Time (in ms)		Number of minor lapses	Number of major lapses	Number of false start
Morning Shift				
Before	328,26	1,61	0,61	0,35
After	364,95	2,26	0,91	0,26
Afternoon Shift				
Before	327,25	1,65	0,35	1,05
After	364,95	2,26	0,91	0,26
Night shift				
Before	293,48	0,65	0,06	0,47
After	350,06	3,65	0,05	0,9

In addition to minor lapses, major lapses remained relatively stable across the morning and afternoon shifts, with slight increases from 0,61 to 0,91 and 0,35 to 0,91, respectively. The night shift, however, showed a minimal change in major lapses. The number of false starts varied across shifts, with a notable increase in false starts during the night shift (from 0,47 to 0,90).

DISCUSSION

The study sample of nurses had an average age of 28,25 years, with a majority being female (83,3 %) and single (75 %). Most nurses had over 3 years of work experience (63,3 %), and the largest group worked in inpatient units (46,7 %). Sleep patterns showed that 93,3 % of nurses slept less than 7 hours a day. In terms of shift work, 38,3 % worked morning shifts, 33,3 % afternoon, and 28,3 %-night shifts. Most nurses were staff nurses (63,3 %), with 51,7 % commuting less than 20 minutes to work. More than 90 % of nurses said they slept for fewer than seven hours per day, which points to a structural problem that may affect both individual health and work output. This trend might be a reflection of larger organizational issues with workforce scheduling and support systems, as the majority are young, unmarried, and still in the early stages of their professions. Interventions that encourage proper sleep and improved work-life balance should be given top priority in hospitals, especially for staff nurses working in high-demand departments like inpatient care. Further supporting the idea that occupational weariness is probably caused more by work-related problems than by outside logistical challenges is the fact that the majority of respondents have tolerable commute times.

Subjective Workload Measurement of Participants

The NASA-TLX questionnaire results on nurses' workload in a hospital highlight key findings. Most nurses reported a high to very high workload, with 60 % scoring in the very high range (80-100) and 37 % in the high range (50-79). Only 3 % reported a medium workload, while no nurses fell into the low or somewhat high categories. Among the workload dimensions, temporal demand was the most challenging, followed by physical and mental demand. Effort exerted by nurses was also significant, with frustration levels indicating considerable emotional strain. These results underscore the heavy workload, especially regarding time and effort. The NASA-TLX scale was used to assess nurses' workload in various studies, providing a subjective rating of workload based on six items, including mental demand, physical demand, temporal demand, performance, effort, and frustration.[11] A comprehensive review and meta-analysis found an average mental workload score of 65,24, with 54 % of nurses reporting high mental workload .[11] This implies that nurses frequently work under considerable pressure, potentially affecting both their performance and the quality of patient care. The findings from NASA-TLX questionnaire studies offer valuable reference data on the workload faced by nurses across various units.[14]

Perceived Fatigue Measurement Of Participants

Table 3 presents the descriptive statistics for the SOFI subscales assessing nurse fatigue. Key findings include the highest mean score for Lack of Energy (4,547 ± 1,0544), indicating significant energy depletion. Sleepiness also showed a notable mean (3,747 ± 0,9969), suggesting widespread drowsiness among nurses. In contrast, Lack of Motivation had a lower mean (2,903 ± 1,0650), indicating a lesser impact. Physical Exertion (2,930 ± 0,7990) and Physical Discomfort (3,053 ± 1,1235) were present but less pronounced. These results underscore the substantial fatigue among nurses, particularly related to energy depletion and sleepiness. SOFI assesses fatigue through five key dimensions: energy depletion, lack of motivation, physical strain, bodily discomfort, and sleepiness.[15,16,18].

The SOFI subscale results show a distinct and concerning pattern of fatigue in nurses, with sleepiness and energy depletion standing out as the main symptoms. The persistently high scores for sleepiness and lack of energy, indicate both possible flaws in institutional fatigue management techniques as well as the physiological toll of rigorous shift work. It's interesting to note that the comparatively low scores for physical exhaustion and lack of motivation imply that, despite their continued dedication and engagement in their jobs, nurses are physically exhausted—an imbalance that might not be long-term viable. This demonstrates the critical need for focused treatments that prioritize task redistribution, sleep hygiene education, and rest optimization in order to protect patient safety and nurse well-being.

Record of Physiological Parameters

EEG measurements of fatigue in nurses across shifts reveal key trends in brain wave activity. Theta and alpha waves, associated with drowsiness and relaxation, decreased after each shift, indicating increased fatigue. Specifically, theta decreased from 9,18 to 8,66 in the morning, 8,72 to 8,34 in the afternoon, and 9,30 to 8,49 at night. Alpha waves also declined, from 6,46 to 5,87 in the morning, 6,96 to 6,24 in the afternoon, and 6,16 to 5,38 at night. Beta waves showed slight decreases, suggesting a decline in alertness. The relative power ratios (RPR) of theta and alpha decreased, while beta remained stable, further indicating increased fatigue. Beta waves (8–30 Hz) are associated with active thought and mental processing. Reduced beta activity, especially in the frontal areas, has been noted in fatigued nurses, indicating a decline in cognitive performance [19]. Elevated delta (0,5–4 Hz) and theta (4–8 Hz) wave activity is linked to drowsiness and lower alertness. Research has found that night-shift nurses display increased delta and theta power while awake, suggesting higher levels of fatigue.[20,21]

The study revealed shifts in autonomic nervous system (ANS) activity in nurses across different work shifts, as indicated by heart rate variability (HRV) measurements. During the morning shift, before the shift, the mean RR was 731,50 ms, HR was 82,91 bpm, and SDNN was 34,19 ms. After the shift, the mean RR increased to 745,25 ms, HR decreased to 81,36 bpm, and SDNN dropped to 30,65 ms, with the LF/HF ratio decreasing from 1,05 to 0,90, indicating parasympathetic dominance. In the afternoon shift, before the shift, the mean RR was 687,85 ms, HR was 88,18 bpm, and SDNN was 29,93 ms, reflecting sympathetic dominance. After the shift, the mean RR increased to 786,33 ms, HR decreased to 77,33 bpm, and SDNN increased to 35,90 ms, with the LF/HF ratio decreasing from 1,45 to 1,32, showing parasympathetic activation. Similarly, a study on physical exhaustion revealed that HRV parameters like SDNN and RMSSD tended to decrease throughout the day, suggesting their potential for estimating physical fatigue accumulated over the course of a day.[22]

During the night shift, before the shift, nurses had a mean RR of 722,04 ms, HR of 83,88 bpm, and SDNN of 31,42 ms. After the shift, the mean RR increased to 803,32 ms, HR dropped to 75,55 bpm, and SDNN rose to 36,52 ms. The LF/HF ratio slightly decreased from 1,76 to 1,57, indicating a shift toward parasympathetic dominance.

These findings suggest that HRV is a reliable indicator of fatigue, showing a clear transition from sympathetic to parasympathetic activity after each shift. This highlights HRV's potential as a tool for monitoring fatigue and aiding recovery in healthcare workers. Previous studies revealed that nurses working night shifts exhibit increased sympathetic activity and reduced parasympathetic activity, as indicated by higher low-frequency (LF) power and LF/HF ratio, and lower high-frequency (HF) power.[23] Heart rate variability (HRV) metrics like low frequency (LF), high frequency (HF), and the root mean square of successive differences (RMSSD) are frequently utilized to assess stress and fatigue. Nurses on extended shifts, particularly night shifts, often show higher LF %, lower LnHF, and reduced RMSSD, suggesting elevated stress and fatigue levels.[24]

Strong physiological proof of nurses' accumulation of weariness during shifts, especially at night, is shown by the EEG and HRV results. Reduced cognitive awareness is indicated by a decrease in theta, alpha, and beta wave activity, whilst changes in HRV measures show important autonomic stress and recovery dynamics. These findings, highlight how critical it is to include weariness as a quantifiable occupational risk. By incorporating EEG and HRV monitoring into regular workforce management, fatigue related impairments may be prevented proactively, promoting patient safety and nursing well-being.

Sleepiness and Alertness Assessment Using PVT

The data shows that reaction times and lapses in performance generally increase after each shift. For the morning and afternoon shifts, reaction times rose by approximately 36 ms, with a noticeable increase in minor and major lapses. The night shift saw the largest increase in reaction time (56 ms) and a significant rise in minor lapses, while false starts also increased. Overall, the night shift showed the most pronounced decline in performance, highlighting the impact of fatigue on cognitive function. These results suggest that shift work, particularly night shifts, contributes to increased fatigue and performance lapses. Previous study revealed that nurses working night shifts generally exhibit greater sleepiness and fatigue compared to those on day shifts, which is reflected in their PVT performance. Night shift nurses tend to have slower reaction times and more performance lapses. Previous study also showed that day shift nurses generally demonstrate better PVT performance, exhibiting quicker reaction times and fewer mistakes than those working night shifts.[25,26]

The negative cognitive consequences of exhaustion on nurses are amply demonstrated by the observed rise in reaction times and performance lapses during all shifts, but especially during the night shift. These results, highlight the urgent need to reevaluate the planning and administration of shift patterns in healthcare settings. Current work patterns may jeopardize patient safety and staff effectiveness, as seen by the marked drop in psychomotor vigilance following night shifts. One useful method for detecting high-risk fatigue states may be to include cognitive performance tests, such the Psychomotor Vigilance Test (PVT), in regular occupational health examinations. This would allow for more targeted fatigue mitigation initiatives and more responsive staffing tactics, especially for night shift workers who are regularly demonstrated to be at higher risk.

Limitations and Cautions

This study has limitations, including its cross-sectional design, small sample from one hospital, and reliance on consumer-grade devices. Single-time-point EEG and PVT data may not capture fatigue changes across shifts. Still, the integration of subjective and objective measures offers valuable insights into nurse fatigue.

CONCLUSIONS

These findings highlight the significant impact of shift work on nurses' workload, fatigue, and cognitive function, emphasizing the need for monitoring to support nurse well-being and patient care. By combining subjective and objective measures, the study offers a comprehensive view of shift work's immediate effects. This has important implications for occupational health and workforce management. Future research should validate these results in diverse populations and evaluate targeted interventions. Reducing nurse fatigue ultimately benefits both staff health and patient safety.

RECOMMENDATIONS

The findings enhance understanding of the interplay between workload, physiology, and cognitive function in shift-working nurses. Notably, night shifts showed pronounced declines in both cognitive performance and physiological markers. These results support the potential of real-time, non-invasive fatigue monitoring to inform shift planning and recovery strategies. Future research should validate these findings in broader populations and assess targeted interventions such as strategic rest, shift rotation, and workload adjustments to improve both staff well-being and patient care outcomes.

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CONFLICT OF INTEREST

Declare potential conflicts of interest; otherwise declare "None" or "The authors declare that there is no conflict of interest".

AUTHORSHIP CONTRIBUTION

Conceptualization: Meilisa Rahmadani.
Data curation: Robiana Modjo.
Formal analysis: Meilisa Rahmadani, L. Meily Kurniawidjaja.

Research: Maya Arlini Puspasari, Mariam Mulia Istiqomah.
Methodology: Maya Arlini Puspasari, Novita Dwi Istanti, Dewi Yunia Fitriani.
Project management: Meilisa Rahmadani.
Resources: Desy Sulistiyorini, Robiana Modjo.
Software: Maya Arlini Puspasari.
Supervision: Robiana Modjo, L. Meily Kurniawidjaja, Maya Arlini Puspasari.
Validation: Meilisa Rahmadani, Novita Dwi Istanti, Dewi Yunia Fitriani.
Display: Desy Sulistiyorini, Mariam Mulia Istiqomah.
Drafting - original draft: Meilisa Rahmadani, Desy Sulistiyorini, Mariam Mulia Istiqomah.
Writing - proofreading and editing: Meilisa Rahmadani, Desy Sulistiyorini.