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STRESS LEVEL AND MENTAL WORKLOA ANALYSIS OF HOSPITAL NURSES WITH SMARTWATCH PHYSIOLOGICAL VALIDATION

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Abstract

Nurses working in critical care units face substantial mental workload and occupational stress, yet most prior studies rely on a single subjective or objective measurement approach. This study examined the mental workload and occupational stress of Intensive Care Unit (ICU) and Emergency Department (IGD) nurses at RSUI Cawas Klaten, Indonesia, and validated subjective instruments against physiological indicators. Using a quantitative descriptive correlational design, data were collected from all 27 ICU and IGD nurses (total sampling) using the NASA Task Load Index (NASA-TLX), the Expanded Nursing Stress Scale (ENSS), and an Apple Watch SE Generation 2 smartwatch recording Heart Rate (HR) and Heart Rate Variability (HRV) across three phases: rest, work, and questionnaire completion. Results showed a High mental workload (mean Weighted Workload = 54.67) dominated by the Effort dimension, and an overall Low Stress level (mean ENSS = 1.95) that approached the Moderate Stress threshold, led by treatment uncertainty and patient/family related stressors. Pearson correlation revealed a significant positive relationship between ENSS and HRV during work ($r = 0.630$, $p < 0.001$) and between NASA-TLX and HR during work ($r = 0.468$, $p = 0.014$), whereas post work measurements showed no significant association. These findings confirm that HR and HRV recorded during active work, rather than after work, are valid physiological indicators for cross validating subjective workload and stress instruments among critical care nurses.

Keywords: Heart Rate Variability; Mental Workload; NASA-TLX; Nursing Stress; Smartwatch.

INTRODUCTION

Mental health is one of the crucial issues in modern human well being (World Health Organization, n.d.). In 2019, more than 450 million people worldwide experienced mental health disorders, with a marked increase among public service workers, particularly in healthcare. In Indonesia, a 2018 survey by the Indonesian National Nurses Association found that approximately 50.9% of nurses experienced work-related stress, characterized by dizziness, fatigue, sleep disturbance, and reduced communication quality (Kurniawati et al., 2024). Susanto et al. (2025) reported that 57.7% of 312 ICU and Emergency Department (IGD) nurses in East Java experienced work stress, driven primarily by excessive workload, night shifts, and limited social support.

RSUI Cawas Klaten, faces similar conditions: preliminary observation found that its 12-nurse ICU recorded ten instances of sick leave and up to 8 hours of monthly overtime within the past six months, with a peak patient to nurse ratio of 4-5:1 during the busiest shifts, while its 15 nurse IGD recorded 14 absences, 2-3 staff turnovers within 1-3 years, 18 hours of monthly overtime, and up to ten monthly patient overload events with a ratio reaching 1:3-5. Such conditions pose serious risks: high mental workload, marked by rapid decision making, multitasking, and emergency demands, can reduce concentration, cause fatigue, and precipitate burnout (Azizah et al., 2025), while chronic occupational stress threatens patient safety and care

quality (Mo et al., 2020). Indonesian Manpower Regulation No. 5/2018 (Article 24) mandates control of psychosocial workplace hazards, including work stress and mental workload.

Accurate measurement of these constructs requires a comprehensive approach. Subjective questionnaires such as the NASA Task Load Index (NASA-TLX) and the Expanded Nursing Stress Scale (ENSS), although reliable and valid, remain susceptible to recall and perception bias (Jordan et al., 2025). Objective physiological measurement can complement subjective data without such bias, but requires validation against the psychological states actually experienced by workers (Vos et al., 2023). Advances in smartwatch technology now enable continuous, non invasive monitoring of physiological variables relevant to early stress detection.

NASA-TLX was selected because it has demonstrated high reliability among nurses (Cronbach's $\alpha = 0.89$; Pourteimour et al., 2021) and strong convergent validity ($r = 0.97$-0.98) compared with alternative workload instruments such as SWAT and the Workload Profile (Longo et al., 2022; Rubio et al., 2004). ENSS was selected for its specificity to the nursing profession, covering nine stress dimensions, namely death and dying, conflict with physicians, inadequate preparation, workload, uncertainty concerning treatment, patients and families, problems with peers, problems with supervisors, and discrimination (French et al., 2000). Its Indonesian version has been validated with excellent reliability (Cronbach's $\alpha = 0.956$; Harsono et al., 2024).

To address the limitations of purely subjective measurement, this study integrated an Apple Watch SE Generation 2 to record Heart Rate (HR) and Heart Rate Variability (HRV) in real time and non invasively. HR reflects cardiovascular activation under stress or high workload, while HRV reflects the balance of the autonomic nervous system between sympathetic (stress) and parasympathetic (relaxation) activity (Meshkati, 1988); reduced HRV indicates elevated stress and reduced adaptive capacity (Li et al., 2023). Prior validation studies report a concordance correlation coefficient of 0.989 at rest and 0.977 under stress between the Apple Watch and the medical grade Polar H7 (Hernando et al., 2018).

Despite growing interest, integration of subjective and objective measurement within a single analytical framework remains scarce, particularly in Indonesian hospital settings. Pourteimour et al. (2021) applied NASA-TLX to 139 COVID-19 ICU nurses relying solely on subjective questionnaires; Harsono et al. (2024) validated the Indonesian ENSS without linking it to workload or wearable data; and Park et al. (2022) demonstrated Apple Watch HRV monitoring during CPR training simulations without a nursing specific stress instrument. This methodological gap motivates the present study, which integrates NASA-TLX, ENSS, and smartwatch based HR/HRV within a single triangulated framework.

Accordingly, this study aims to (1) describe the level and characteristics of mental workload and occupational stress among ICU and IGD nurses at RSUI Cawas Klaten, (2) analyze the correspondence between subjective (NASA-TLX, ENSS) and objective physiological (HR, HRV) measurements, and (3) formulate evidence based recommendations to minimize nurses' stress and mental workload.

LITERATURE REVIEW

Research on occupational stress and mental workload among nurses has employed diverse methodological approaches, yet most have not integrated subjective and objective measurement, nor tested such integration in real clinical settings in Indonesia.

Several studies used NASA-TLX to assess nurses' mental workload. Pourteimour et al. (2021) found a high mean workload (67.14) among 139 Iranian COVID-19 unit nurses using subjective questionnaires alone. Utomo et al. (2024) reported a similarly high mean workload (68.36) among 48 NICU nurses in Indonesia, with the Effort dimension dominant; 91.67% of nurses reported omitting at least one of 21 neonatal care components. Tubbs-Cooley et al. (2018) confirmed that a four dimension NASA-TLX factor structure (mental, physical, temporal demand, and effort) is more stable than the original six-dimension model for ICU populations. Nur et al. (2020) found the highest workload scores among junior nurses (0-3 years of service) in Banda Aceh. Shoja et al. (2020) reported strong instrument reliability ($\alpha = 0.897$) when evaluating COVID-19's impact on 495 Iranian healthcare workers. Fikri et al. (2024) found a significant correlation ($r = 0.312$, $p = 0.002$) between mental workload and stress among 96 inpatient unit nurses in Malang. None of these studies, however, incorporated physiological validation.

Regarding ENSS based stress research, Harsono et al. (2024) validated the Indonesian ENSS ($\alpha = 0.956$) without linking it to workload or wearable measures. Tsegaw et al. (2022) found 48.4% of 304 Ethiopian nurses experiencing work stress, with ICU and operating room staff most affected. Babapour et al. (2022) reported that stress explained 27.9% of the variance in nurses' quality of life. Chatzigianni et al. (2018) documented moderate stress (mean = 136.27) among Greek regional hospital nurses, while Said and El-Shafei (2021) found 75.2% of Egyptian triage hospital nurses experiencing high stress during COVID-19. All of these studies relied exclusively on

subjective instruments.

A separate stream of research has validated smartwatch derived HRV as a stress biomarker. Velmovitsky et al. (2022) showed that Apple Watch ECG derived HRV effectively predicts stress (74.3% sensitivity, 81.2% specificity) in a 50 participant pilot study. Hernando et al. (2018) reported concordance correlation coefficients of 0.989 (relaxed) and 0.977 (stressed) compared with the Polar H7 reference device. Park et al. (2022) found that HRV declines during acute stress in CPR training simulations among nurses. Can et al. (2019) demonstrated that subjective stress does not always align with physiological stress in real life, high intensity settings. Agarwal et al. (2023) further confirmed the feasibility of wearable devices for continuous physiologic monitoring among emergency nurses and residents during actual clinical shifts.

Overall, these studies reveal a clear gap: no Indonesian hospital based study has simultaneously combined subjective (NASA-TLX, ENSS) and objective physiological (HR, HRV) measurement within one triangulated analytical framework. This study addresses that gap.

Theoretically, occupational stress is defined as the relationship between a person and the work environment, appraised as taxing or exceeding one's resources and endangering well-being (Lazarus & Folkman, 1984), while mental workload reflects the cognitive and physical demands imposed by a task relative to an operator's capacity (Hart & Staveland, 1988; Longo et al., 2022). HRV, as an index of autonomic balance, provides an objective, continuous, and non invasive proxy for physiological stress that complements subjective self report (Meshkati, 1988).

Based on this framework, three hypotheses were formulated:

1. H1: There is a significant positive correlation between occupational stress scores measured by ENSS and HRV recorded by the smartwatch among ICU and IGD nurses.
2. H2: There is a significant positive correlation between mental workload scores measured by NASA-TLX and HR recorded by the smartwatch among ICU and IGD nurses.
3. H3: There is a significant difference in smartwatch recorded HRV and HR between nurse groups differentiated by ENSS and NASA-TLX scores.

METHOD

This study used a quantitative descriptive correlational design to characterize nurses' mental workload, occupational stress, and physiological responses, and to examine the correspondence between subjective and objective measures. The study was conducted at Rumah Sakit Umum Islam (RSUI) Cawas Klaten, a type C hospital operating under the Klaten Hajj Pilgrims Foundation since 2004, selected because of its active ICU and IGD units. Data collection took place from November to December 2025.

The study population comprised all nurses on duty in the ICU and IGD (N = 27), recruited through total sampling given the small and fully accessible population. Instruments included the ENSS, the NASA-TLX, and a demographic data sheet covering age, sex, work experience, education, and unit. Physiological data were collected using an Apple Watch SE Generation 2 synchronized via the Apple Health application. Measurement followed three sequential phases for each nurse: (1) a 5 minute resting baseline HR measurement, (2) continuous HR and HRV recording during one hour of active work, and (3) HR and HRV recording during approximately 15 minutes of questionnaire completion at the end of the shift. The NASA-
TLX and ENSS questionnaires were administered at the end of each nurse's shift.

Data were analyzed descriptively to characterize workload, stress, and physiological profiles overall and by unit (ICU vs. IGD). A Shapiro-Wilk normality test ($\alpha = 0.05$) determined the appropriate correlation test for each variable pair: Pearson's product moment correlation for normally distributed data, and Spearman's rank correlation otherwise. All statistical analyses were performed using SPSS.

Raw scores from each instrument were classified into categories using the standard interpretation criteria summarized in Table 1, which were subsequently used to label the descriptive results reported in the Results and Discussion section.

Table 1. Score Interpretation Criteria for NASA-TLX, ENSS, and Smartwatch HRV

Instrument	Score Range	Category
	0 - 9	Low

NASA-TLX (WWL)	10 - 29	Moderate
	30 - 49	Fairly High
	50 - 79	High
	80 - 100	Very High
ENSS (mean score)	= 1.00	No Stress
	1.00 < mean < 2.00	Low Stress
	2.00 ≤ mean < 3.00	Moderate Stress
	> 3.00	High Stress
HRV (smartwatch, %)	1% - 20%	Good
	21% - 60%	Normal
	61% - 80%	Moderate Stress
	81% - 100%	High Stress

Note. NASA-TLX category thresholds adapted from Soewardi and Kusuma (2019); ENSS category thresholds adapted from Dinh et al. (2024); HRV category thresholds follow the built in stress scoring scale of the Stresswatch application, a proprietary, non peer reviewed vendor source used as reported in the original thesis and retained here for consistency with the source data.

RESULTS AND DISCUSSION

1. Respondent Characteristics

A total of 27 nurses participated in this study: 17 women (63.0%) and 10 men (37.0%), aged 24-44 years, with 15 nurses from the IGD and 12 from the ICU. Work tenure ranged from 0.3 to 20.3 years. Most respondents held a Bachelor's degree in Nursing (S1 Ners; n = 23, 85.2%), while the remainder held a Nursing Diploma (D3; n = 4, 14.8%), as summarized in Table 2.

Table 2. Respondent Characteristics (N = 27)

Characteristic	Category	n	%
Sex	Female	17	63.0
	Male	10	37.0
Unit	IGD	15	55.6
	ICU	12	44.4
Education	S1 Ners (Bachelor)	23	85.2
	D3 (Diploma)	4	14.8
Age range	24-44 years	-	-
Tenure range	0.3-20.3 years	-	-

Mental Workload (NASA-TLX)

The overall NASA-TLX analysis yielded a mean total score of 820.00 and a mean Weighted Workload (WWL) of 54.67, which falls within the high category, just above the Fairly High/High boundary. Table 3 presents the mean score for each of the six NASA-TLX dimensions.

Table 3. Mean NASA-TLX Dimension Scores (N = 27)

Dimension	Mean Score
Mental Demand (MD)	124.07
Physical Demand (PD)	114.44
Temporal Demand (TD)	125.19
Own Performance (OP)	168.15
Effort (EF)	208.15
Frustration (FR)	80.00
Total Workload	820.00
Weighted Workload (WWL)	54.67

The Effort dimension obtained the highest mean score (208.15), indicating that nurses consistently perceived the need to exert considerable effort to complete their tasks, a finding consistent with Nur et al. (2020), who likewise identified Effort as the dimension with the greatest impact on ICU and IGD nurses. Own Performance ranked second (168.15), reflecting a generally favorable sense of self efficacy despite the demanding workload. Temporal Demand (125.19) and Mental Demand (124.07) were both elevated, reflecting continuous concentration requirements under time pressure, while Physical Demand (114.44) remained substantial. Frustration recorded the lowest mean (80.00), again consistent with Nur et al. (2020).

Unit level comparison showed that ICU nurses recorded a slightly higher workload (WWL = 55.72; total = 835.83) than IGD nurses (WWL = 53.82; total = 807.33); both values likewise fall within the High category. ICU nurses showed particularly elevated Effort (208.33), Mental Demand (176.67), and Frustration (110.83) scores, reflecting the cognitive load and emotional pressure of managing critically ill patients under close monitoring. IGD nurses, by contrast, showed a persistently high Effort score (208.00) alongside elevated Own Performance (198.67) and Physical Demand (147.33), reflecting the physically dynamic and variable nature of emergency patient handling.

Occupational Stress (ENSS)

The mean ENSS score across all respondents was 1.95 (SD = 0.49). Per the interpretation criteria in Table 1, this falls within the Low Stress band (1.00 < mean < 2.00), positioned just below the Moderate Stress threshold of 2.00. Table 4 ranks the nine ENSS subscales by mean score and corresponding category.

Table 4. Mean ENSS Subscale Scores, Ranked (N = 27)

Subscale	Mean	SD	Category
Uncertainty concerning treatment	2.13	0.50	Moderate Stress
Patients and families	2.11	0.70	Moderate Stress
Conflict with physicians	2.01	0.52	Moderate Stress
Conflict with supervisors	1.97	0.60	Low Stress
Discrimination	1.94	0.96	Low Stress
Workload	1.93	0.96	Low Stress
Death and dying	1.92	0.54	Low Stress
Emotional demands	1.72	0.46	Low Stress
Conflict with peers	1.53	0.43	Low Stress
Overall ENSS score	1.95	0.49	Low Stress

Only three subscales, uncertainty concerning treatment, patients and families, and conflict with physicians, reached the Moderate Stress category, while the remaining six subscales, together with the overall score, fell within the Low Stress band. The two highest ranked subscales, uncertainty concerning treatment and patients/families, are both non structural, clinical, and interpersonal in nature, indicating that the principal source of stress lies in direct interaction with clinical uncertainty and external demands rather than in organizational structure. Conflict with supervisors occupied a middle rank within the Low Stress band, while conflict with peers was the lowest and most consistent source of stress (SD = 0.43), suggesting that horizontal relationships among nurses remain the most stable aspect of the work environment in both units.

Demographic analysis further revealed that mental workload and occupational stress tended to decrease with age and tenure, with nurses aged 20-30 years and those with 0-3 years of service recording the highest scores. Female nurses reported a higher overall workload than male nurses, most notably in the temporal demand dimension. Nurses holding an S1 Ners degree reported higher mental demand and frustration than those with a D3 qualification, possibly reflecting greater awareness of care standards and systemic inefficiencies. Night shifts recorded the highest mean ENSS score (2.22), compared with morning (1.91) and afternoon shifts (1.81), with discrimination and treatment uncertainty subscales showing the largest night shift elevation.

Physiological Measures (HR and HRV)

Table 5 presents descriptive statistics for HR and HRV across the three measurement phases. All 27 respondents recorded a resting HR within the normal clinical range (60-100 bpm), confirming healthy cardiovascular baselines prior to each shift. Mean HR rose sharply during work to 111.74 bpm (delta = +36.11 bpm), with 21 of 27 nurses (77.8%) exceeding 100 bpm, before declining to 84.52 bpm during questionnaire completion, still above the resting baseline. Mean HRV during work was 75.37%, which falls within the Moderate Stress band of the smartwatch HRV criteria (61-80%; Table 1); it then moved to 58.30% during questionnaire completion (delta = -17.07%), nominally within the Normal band (21-60%). Because this apparent shift occurs immediately after intense physical activity, it most plausibly reflects an incomplete and still fluctuating autonomic recovery process rather than a genuine reduction in stress, a pattern also reported by Park et al. (2022).

Table 5. Descriptive Statistics of HR and HRV (N = 27)

Variable	Mean	SD	Min	Max	Median
HR - Rest (bpm)	75.63	4.96	61	83	77
HR - Work (bpm)	111.74	14.21	90	140	109
HR - Questionnaire (bpm)	84.52	10.60	71	106	81
HRV - Work (%)	75.37	14.69	50	100	74
HRV - Questionnaire (%)	58.30	18.67	35	100	52

Table 6. HR and HRV by Unit (Mean ± SD)

Variable	ICU	IGD
HR Rest (bpm)	73.58 ± 6.07	77.27 ± 3.22
HR Work (bpm)	108.33 ± 15.48	114.48 ± 13.00
HRV Work (%)	74.08 ± 16.56	76.40 ± 13.51
HRV Questionnaire (%)	60.42 ± 16.70	56.60 ± 20.52

IGD nurses showed a larger HR increase during work (+37.20 bpm) and a larger HRV decline during questionnaire completion (-19.80%) than ICU nurses, consistent with the more unpredictable physical and cognitive demands of emergency triage work. These unit level patterns are descriptive; formal inferential testing of between group differences (H3) was beyond the scope of the correlation analyses reported here and is recommended for future confirmatory studies.

Hypothesis Testing: Correspondence Between Subjective and Objective Measures

Table 7 summarizes the correlation analyses used to test H1 and H2. Normality was assessed with the Shapiro-Wilk test ($\alpha = 0.05$); Pearson's correlation was applied to normally distributed pairs and Spearman's rank correlation otherwise.

Table 7. Correlation Between Subjective and Objective Measures (N = 27)

Variable Pair	Test	r	p	Result
ENSS - HRV (Work)	Pearson	0.630	< 0.001	Significant
ENSS - HRV (Questionnaire)	Spearman	0.223	0.263	Not significant
NASA-TLX - HR (Rest)	Spearman	-0.066	0.745	Not significant
NASA-TLX - HR (Work)	Pearson	0.468	0.014	Significant
NASA-TLX - HR (Questionnaire)	Spearman	0.185	0.356	Not significant

The Pearson correlation between ENSS score and HRV during work was strong, positive, and significant ($r = 0.630$, $p < 0.001$), indicating that rising occupational stress scores were accompanied by physiologically detectable reductions in heart rate variability during active shifts. This supports H1 and is consistent with Can et al. (2019), who found that HRV declines as workload increases in real life, high intensity settings. In contrast, the correlation between ENSS and HRV recorded during questionnaire completion was not significant ($r = 0.223$, $p = 0.263$), which can be explained physiologically: HRV measured after work reflects the body's recovery phase rather than the actual workload experienced during the shift, consistent with the emphasis of Can et al. (2019) on measurement timing as a critical determinant of triangulation validity.

The Pearson correlation between NASA-TLX score and HR during work was positive, moderate, and significant ($r = 0.468$, $p = 0.014$), confirming that higher perceived mental workload was accompanied by a proportionally elevated heart rate during active shifts. This partially supports H2: the physiological correspondence was confirmed only for the work phase. HR at rest ($r = -0.066$, $p = 0.745$) and during questionnaire completion ($r = 0.185$, $p = 0.356$) showed no significant association with NASA-TLX scores. Resting HR is primarily determined by intrinsic cardiovascular fitness rather than cognitive demand, while post work HR reflects a partial and still incomplete recovery process rather than the workload actually experienced.

Taken together, these results demonstrate that the correspondence between subjective and objective measures is valid only when physiological data are recorded concurrently with the activity being evaluated: ENSS with HRV during work, and NASA-TLX with HR during work. This finding underscores the critical importance of measurement timing in subjective objective triangulation research on occupational stress and mental workload, and suggests that real time, work concurrent physiological monitoring, rather than post hoc measurement, offers the more valid basis for hospital workload and stress surveillance systems.

CONCLUSION

This study characterized the mental workload and occupational stress of ICU and IGD nurses at RSUI Cawas Klaten and examined the correspondence between subjective instruments and objective physiological indicators. Overall mental workload fell within the High category (mean WWL = 54.67), driven primarily by the Effort dimension, with ICU nurses slightly more burdened than IGD nurses. Occupational stress was, on average, within the Low Stress band while closely approaching the Moderate Stress threshold (mean ENSS = 1.95), with three subscales, treatment uncertainty, patients/families, and physician conflict, individually reaching the Moderate Stress category; stress was dominated by clinical uncertainty and patient/family related stressors rather than interpersonal conflict. Night shift nurses, female nurses, younger and less experienced nurses, and S1 Ners qualified nurses reported comparatively higher workload or stress.

Hypothesis testing confirmed that subjective-objective correspondence is context specific: H1 was supported (ENSS-HRV during work: $r = 0.630$, $p < 0.001$), and H2 was partially supported (NASA-TLX-HR during work: $r = 0.468$, $p = 0.014$), while post work measurements of both HR and HRV showed no significant relationship with the

subjective scores. H3 was examined descriptively through unit level comparison rather than formal inferential testing and warrants confirmatory analysis in future research. These findings establish that HR and HRV recorded concurrently with active work, rather than afterward, provide a valid physiological basis for cross validating nurses' self reported workload and stress.

Based on these findings, RSUI Cawas Klaten is recommended to (1) implement real time HRV monitoring via smartwatch as an early detection system for physiological fatigue and stress, (2) redesign shift rotation and rest schedules using objective cardiovascular data, (3) develop career stage specific psychosocial interventions, from structured mentoring for junior nurses to recognition based programs for senior nurses, (4) strengthen support for night shifts through improved staffing ratios and evidence based fatigue management programs, and (5) tailor competency development approaches to the distinct workload profiles of S1 Ners and D3 nurses.

This study is limited by its cross sectional, single site design and modest sample size (N = 27), relatively brief physiological measurement windows, and uncontrolled confounders such as caffeine intake, sleep quality, and physical activity outside work. Future research should extend this triangulated approach to a larger and more geographically diverse sample across multiple hospital units, adopt a longitudinal or prospective cohort design to capture change over time, use higher accuracy medical grade devices, formally test group based physiological differences (H3), and explore machine learning models that integrate subjective and real time physiological data for adaptive, evidence based nurse workload and stress monitoring.

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