Stress, Anxiety, and Depression Are Linked to Heart Rate Variability in Indonesian Anesthesiology and Intensive Therapy Residents: A Cross-Sectional Study

Dhikrulloh Anwar[1], Prananda Surya Airlangga[2], Raden Argarini[3], Izzatul Fithriyah[4], Hanif Ardiansyah Sulistya[5]

[1,2] *Department of Anesthesiology and Intensive Therapy, Faculty of Medicine, Universitas Airlangga / Dr. Soetomo General Academic Hospital, Surabaya, Indonesia*

[3] *Department of Medical Physiology and Biochemistry, Faculty of Medicine – UNIVERSITAS AIRLANGGA, Surabaya, Indonesia*

[4] *Department of Psychiatry, Faculty of Medicine, Universitas Airlangga / Dr. Soetomo General Academic Hospital, Surabaya, Indonesia*

[5] *Faculty of Medicine, Universitas Airlangga / Dr. Soetomo General Academic Hospital, Surabaya, Indonesia*

KEYWORDS

Depression, Anxiety, Psychological Stress, DASS-21, Heart Rate, Anesthesiology

ABSTRACT:

Introduction: Psychological stress is a global health issue affecting both mental and physical well-being, particularly among residents. Anesthesiology residency training is recognized as highly stressful, potentially impacting cardiovascular health. **Objectives:** This study aims to assess the relationship between psychological stress levels and heart rate variability (HRV) in anesthesiology and intensive therapy residents. **Methods:** This cross-sectional study was conducted in April–May 2024 at Dr. Soetomo General Academic Hospital, Surabaya, Indonesia. Psychological stress was assessed using the DASS-21 questionnaire. HRV parameters (time and frequency domains) were measured using Actiheart software version 4.0.116. Sociodemographic data were collected for analysis. Spearman's correlation test was performed to examine relationships between HRV, psychological stress, and sociodemographic variables using SPSS 27. **Results:** Of the 89 residents, the mean age was 31.07 years. Depression, anxiety, and stress levels were observed in 18%, 24.7%, and 21.3% of residents, respectively. Significant negative correlations were found between HRV parameters (e.g., SDNN, RMSSD, VLF) and the depression and stress subscales (e.g., SDNN $r = -0.214$, $p = 0.044$; VLF $r = -0.278$, $p = 0.008$). Fewer correlations were observed with the anxiety subscale. Sociodemographic analysis showed a positive correlation between years of education and depression levels ($r = 0.311$, $p = 0.003$). **Conclusions:** Psychological stress, particularly depression and stress, was negatively correlated with HRV parameters, indicating impaired autonomic regulation. HRV may serve as a potential biomarker for monitoring psychological health in anesthesiology residents and warrants further exploration for preventive and early intervention strategies.

1. Introduction

Stress represents an interaction between biological and psychological processes in response to environmental challenges [1]. It is recognized as a global concern affecting professionals across various fields, including healthcare. Residency training, particularly in anesthesiology and intensive therapy, is associated with heightened stress levels due to demanding workloads, long hours, and the need for rapid and precise decision-making. Previous studies have highlighted this issue; for instance, 75% of anesthesiology residents in a 2021 study at Universitas Airlangga reported moderate stress levels, primarily caused by unexpected events, workload-induced anxiety, and a lack of perceived control in daily life [2]. Similarly, research in Abu Dhabi identified that 86.4% of residents experienced stress, with 50.8% reporting depression and 65.7% emotional exhaustion [3].

The consequences of chronic stress among residents are profound, ranging from burnout, fatigue, and reduced cognitive function to increased risks of errors and substance misuse. Sleep deprivation during extended shifts further exacerbates these effects, impairing the prefrontal cortex and diminishing critical cognitive abilities such as concentration, creativity, and decision-making [4]. Additionally, prolonged stress has been linked to a higher chance of developing heart-related issues such as hypertension, coronary artery disease, and stroke, with mortality rates reported to be two to five times higher in affected individuals [5], [6].

Heart rate variability (HRV), a non-invasive and reproducible measure of autonomic nervous system activity, offers a quantitative means to assess the physiological impact of psychological stress [7]. The autonomic nervous system's sympathetic and parasympathetic branches are vital for the body's response to stress, and prolonged stress can lead to a decrease in HRV, suggesting a decrease in the body's ability to adapt [8]. Although HRV has been extensively studied as a biomarker for stress, its application among anesthesiology residents remains underexplored.

2. Objectives

This study aims to investigate the relationship between psychological stress, including depression, anxiety, and stress levels assessed using the DASS-21 scale, and HRV parameters in anesthesiology and intensive therapy residents at Universitas Airlangga. The findings are expected to contribute to strategies for stress management and preventive measures to enhance both mental and cardiovascular health in this vulnerable population.

3. Methods

This research project employed an analytical observational design with a cross-sectional approach to thoroughly examine the correlation between psychological stress levels and heart rate variability (HRV) in anesthesiology and intensive therapy residents studying at the prestigious Faculty of Medicine, Universitas Airlangga. This approach allowed for a comprehensive analysis of the relationship between these two variables, shedding light on the potential impact of stress on cardiac health among medical professionals. The study was conducted between April 2024 and May 2024 at Dr. Soetomo General Academic Hospital, Surabaya. Ethical approval for this study was granted by the Institutional Review Board (IRB) of the Health Research Ethics Committee, Dr. Soetomo General Academic Hospital (IRB No. 0963/KEPK/IV/2024), in compliance with the Declaration of Helsinki

2013. All individuals who took part in the study willingly gave their consent in writing after being fully informed about the purpose and procedures of the research. The confidentiality of each participant was carefully safeguarded, ensuring that their personal information remained undisclosed throughout the study. This report follows the guidelines set out in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [9].

The study population consisted of all anesthesiology and intensive therapy residents actively enrolled at the Faculty of Medicine, Universitas Airlangga, during 2024. We managed to recruit 89 participants, exceeding the minimum sample size of 87, which was calculated using the cross-sectional study formula [10]. Participants were recruited using purposive random sampling and were required to meet inclusion criteria: aged 20–40 years, actively enrolled as residents, no history of cardiovascular or chronic illnesses affecting outcomes (e.g., asthma, cancer), and abstinence from smoking, caffeine, or alcohol for 24 hours prior to data collection. Exclusion criteria included unwillingness to participate.

Data collection involved administering socio-demographic surveys, physical examinations, and validated questionnaires. The socio-demographic data collected included age, gender, height, weight, BMI, level of physical activity, marital status, employment status, and other relevant factors. Psychological stress levels were assessed using the DASS-21 questionnaire, which evaluates depression, anxiety, and stress subscales [11]. The scores for each specific area were divided into five different categories based on the severity of the symptoms observed: normal, mild, moderate, severe, and extremely severe. To assess participants' level of physical activity, the researchers utilized the International Physical Activity Questionnaire (IPAQ).

Participants underwent a brief physical examination, including blood pressure and resting pulse measurements after sitting for at least 5 minutes. HRV data were obtained using the Actiheart version 4.0.116, a validated device capable of measuring heart rate and activity parameters. HRV measurements included time-domain parameters (SDNN, RMSSD, SDANN, and TI) and frequency-domain parameters (VLF, LF, HF, and LF/HF ratio). Measurements were conducted in a controlled environment with participants in a supine position to ensure data consistency.

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA). Continuous data were presented as means ± standard deviation or median (interquartile range), depending on the distribution. Relationships between psychological stress levels and HRV parameters were analyzed using Spearman’s correlation test, with a significance level set at $p < 0.05$.

4. Results

Of the 135 anesthesiology and intensive therapy residents approached, 46 were excluded for the following reasons: refusal to participate (n = 24), scheduling conflicts due to shift duties (n = 20), or medical history (cardiovascular condition, n = 1; asthma, n = 1). A total of 89 residents were enrolled and included in the analysis, as depicted in the flow diagram of participant recruitment [Figure 1].

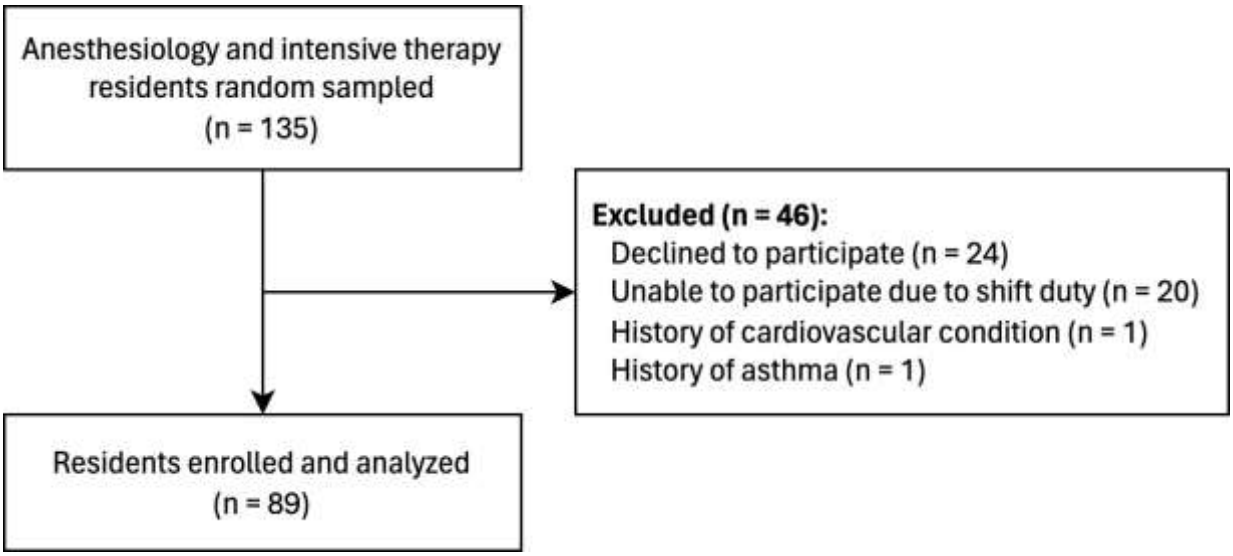

Figure 1: Study participants flow diagram

Table 1: General characteristics of study participants

Variables	Male (n=68)	Female (n=21)
Age (years), mean±SD	31.07±2.98	30.90±3.05
Body weight (kg), mean±SD	78.16±15.07	65.55±14.88
Body height (cm), mean±SD	170.35±6.29	158.76±7.42
BMI (kg/m²), mean±SD	26.82±4.37	25.84±4.87
Length of study (months), median (IQR)	34 (41)	22 (15)
Physical activity (METs-min/week), median (IQR)	3226 (5556)	7101 (6930)
Marital status, n (%)		
Single	15 (16.9)	13 (14.6)
Married	53 (59.5)	8 (9.0)
Employment status, n (%)		
Government	15 (16.8)	8 (9.0)
Private	53 (59.6)	13 (14.6)
Funding status, n (%)		
Self-funded	49 (55.0)	15 (16.9)
Scholarship	19 (21.4)	6 (6.7)
Smoking status, n (%)		
Non-smoker	54 (60.7)	20 (22.4)
Smoker	14 (15.8)	1 (1.1)
Physical activity level, n (%)		
Light	3 (3.4)	1 (1.1)
Moderate	26 (29.2)	5 (5.6)
Vigorous	39 (43.8)	15 (16.9)

BMI: Body mass index; **METs**: Metabolic equivalent of task

Table 1 displays the characteristics of participants. Among them, 68 were male (76.4%) and 21 were female (23.6%), with a mean age of 31.07 years (SD 2.98). The median duration of education was 28 months (IQR 36), with males reporting a median of 34 months (IQR 41) and females 22 months (IQR

15). Most residents were married (68.5%), worked in private institutions (74.2%), self-funded their education (71.9%), were non-smokers (83.1%), and engaged in vigorous physical activity (60.7%).

Table 2: HRV parameters and DASS-21 subscale scores of study participants

Variables	Male (n=68)	Female (n=21)
HRV time domain, median (IQR)		
SDNN (ms)	58.21 (31.85)	57.77 (21.41)
RMSSD (ms)	34.25 (29.41)	42.44 (25.78)
SDANN (ms)	17.00 (14.90)	14.70 (19.00)
TI	14 (7)	14 (5)
HRV frequency domain, median (IQR)		
VLF (ms^2)	835.50 (791.00)	745.00 (775.00)
LF (ms^2)	665.50 (595.00)	636.00 (828.00)
HF (ms^2)	276.50 (577.00)	374.00 (592.00)
LF/HF ratio	1.95 (2.48)	1.27 (1.34)
DASS-21 depression subscale, n (%)		
Normal	56 (62.9)	17 (19.1)
Mild	5 (5.6)	3 (3.4)
Moderate	3 (3.4)	1 (1.1)
Severe	3 (3.4)	0 (0)
Extremely severe	1 (1.1)	0 (0)
DASS-21 anxiety subscale, n (%)		
Normal	51 (57.3)	16 (18.0)
Mild	8 (9.0)	2 (2.2)
Moderate	6 (6.7)	1 (1.1)
Severe	2 (2.2)	1 (1.1)
Extremely severe	1 (1.1)	0 (0)
DASS-21 stress subscale, n (%)		
Normal	54 (60.7)	16 (18.0)
Mild	5 (5.6)	2 (2.2)
Moderate	6 (6.7)	1 (1.1)
Severe	2 (2.2)	1 (1.1)
Extremely severe	2 (2.2)	0 (0)

HRV: Heart rate variability; **SDNN**: standard deviation of N-N intervals; **RMSSD**: root mean square of successive RR interval differences; **SDANN**: standard deviation of the average of NN intervals; **TI**: triangular index; **VLF**: very low frequency power; **LF**: low frequency power; **HF**: high frequency power; **LF/HF ratio**: low frequency to high frequency ratio; **DASS-21**: Depression, anxiety, and stress scale

Table 2 displays the HRV parameters and subscales of DASS-21. In the time domain, the median SDNN was 58.18 ms (IQR 29.90 ms), and the median RMSSD was 38.31 ms (IQR 28.99 ms). For frequency-domain parameters, the median VLF, LF, HF, and LF/HF ratio were 786.00 ms^2 (IQR 791.00), 653.00 ms^2 (IQR 660.00), 305.00 ms^2 (IQR 566.00), and 1.91 (IQR 2.21), respectively. As for the DASS-21 subscales, 18% of participants showed depressive symptoms, with most cases classified as mild (9%). For anxiety, 24.7% exhibited symptoms, with the severity most commonly at mild and moderate levels (10.1% each). Meanwhile, 21.3% of participants experienced stress, with most cases also classified as mild and moderate (7.9% each).

Table 3: Correlation between psychological DASS-21 domains and HRV

Variables	Psychological DASS-21 domains					
	Depression		Anxiety		Stress	
	r	p-value	r	p-value	r	p-value
HRV time domain						
SDNN	-0.214	0.044*	-0.145	0.175	-0.243	0.022*
RMSSD	-0.276	0.009*	-0.081	0.453	-0.224	0.035*
SDANN	-0.224	0.035*	-0.157	0.142	-0.243	0.022*
TI	-0.226	0.033*	-0.140	0.192	-0.181	0.089*
HRV frequency domain						
VLF	-0.278	0.008*	-0.224	0.035*	-0.342	0.001*
LF	-0.143	0.183	-0.096	0.370	-0.210	0.048*
HF	-0.236	0.026*	-0.042	0.696	-0.166	0.121
LF/HF ratio	0.227	0.032*	-0.014	0.893	0.077	0.475

*p-value significant at < 0.05; r = coefficient of correlation; **HRV**: Heart rate variability; **SDNN**: standard deviation of N-N intervals; **RMSSD**: root mean square of successive RR interval differences; **SDANN**: standard deviation of the average of NN intervals; **TI**: triangular index; **VLF**: very low frequency power; **LF**: low frequency power; **HF**: high frequency power**; LF/HF ratio**: low frequency to high frequency ratio; **DASS-21**: Depression, anxiety, and stress scale

Table 3 displays the relationship between psychological DASS-21 domains (depression, anxiety, and stress) and HRV parameters which reveals several significant correlations. Within the HRV time domain, depression is significantly negatively correlated with SDNN (r = -0.214, p = 0.044), RMSSD (r = -0.276, p = 0.009), SDANN (r = -0.224, p = 0.035), and TI (r = -0.226, p = 0.033). Stress also shows significant negative correlations with SDNN (r = -0.243, p = 0.022), RMSSD (r = -0.224, p = 0.035), and SDANN (r = -0.243, p = 0.022). Anxiety, however, does not exhibit statistically significant correlations with any time-domain HRV parameter. In the HRV frequency domain, depression is significantly negatively correlated with VLF (r = -0.278, p = 0.008) and HF (r = -0.236, p = 0.026). Stress shows a similar significant negative relationship with VLF (r = -0.342, p = 0.001) and LF (r = -0.210, p = 0.048). Anxiety, in contrast, does not demonstrate significant correlations with any frequency-domain parameters.

Table 4: Correlation between psychological DASS-21 domains and sociodemographic characteristics

Variables	Psychological DASS-21 domains					
	Depression		Anxiety		Stress	
	r	p-value	r	p-value	r	p-value
Age	0.007	0.948	-0.159	0.135	-0.012	0.910
Sex	-0.014	0.899	0.045	0.675	0.051	0.633
Body weight	0.097	0.364	0.087	0.420	0.026	0.806
Body height	0.089	0.404	0.023	0.827	-0.053	0.620
BMI	0.083	0.440	0.106	0.321	0.071	0.510
Length of study	0.311	0.003*	0.023	0.831	0.069	0.522
Marital status	0.018	0.866	-0.027	0.803	0.011	0.916
Employment status	0.048	0.657	0.143	0.182	0.060	0.575
Funding status	0.002	0.985	-0.150	0.160	-0.101	0.345

Variables	Psychological DASS-21 domains					
	Depression		Anxiety		Stress	
	r	p-value	r	p-value	r	p-value
Smoking status	0.100	0.352	0.070	0.514	0.120	0.261
Physical activity level	-0.134	0.211	0.005	0.960	-0.112	0.297

*p-value significant at < 0.05; r = coefficient of correlation; **BMI**: Body mass index; **DASS-21**: Depression, anxiety, and stress scale

Table 4 highlights the correlation between psychological DASS-21 domains and sociodemographic characteristics. Among the variables analyzed, only length of study exhibits a substantial positive association with depression ($r = 0.311$, $p = 0.003$). None of the other sociodemographic variables, including age, sex, BMI, smoking status, or physical activity level, show statistically significant correlations with depression, anxiety, or stress domains. This suggests that longer study duration is associated with higher levels of depression, while other sociodemographic factors have no notable impact on psychological stress levels or anxiety in this cohort.

5. Discussion

This study explored the correlation between psychological stress levels, as measured by the DASS-21 subscales (depression, anxiety, and stress), and heart rate variability (HRV) parameters in anesthesiology and intensive therapy residents at Universitas Airlangga. The findings demonstrated significant negative correlations between depression and stress with HRV parameters, while anxiety exhibited fewer significant associations. These results suggest autonomic dysfunction as a potential mechanism underlying psychological stress in this population.

Participants were predominantly male (76.4%), reflecting gender disparities often observed in anesthesiology residency programs [12], [13]. Males exhibited higher median HRV values across key parameters such as SDNN, RMSSD, and LF/HF ratio compared to females, supporting previous findings on gender-specific physiological stress responses [14]. While the majority of residents reported normal psychological states across all DASS-21 subscales, a subset experienced mild to severe levels of depression, anxiety, or stress, underscoring the need for targeted mental health interventions in this high-demand setting [15].

Depression showed significant negative correlations with HRV parameters, including SDNN, RMSSD, SDANN, VLF, and HF. These findings align with prior studies that have linked lower HRV to impaired autonomic balance in individuals with depression [7], [16]. Reduced HRV reflects disruptions in sympathetic-parasympathetic regulation and may serve as a biomarker for identifying residents at risk of mood disorders, particularly in high-stress environments [17], [18]. Although LF/HF ratio is often used as an indicator of autonomic balance, it did not show significant associations, suggesting that other HRV parameters may be more sensitive in detecting depressive symptoms.

Anxiety presented fewer significant correlations with HRV, with only VLF demonstrating a weak negative association. This result is consistent with studies suggesting that anxiety's impact on autonomic function may vary depending on its type and severity [19], [20]. The variability in HRV responses to anxiety highlights the complexity of its autonomic regulation mechanisms, which may involve both sympathetic and parasympathetic components. These findings support the need for

complementary assessments, such as hormone levels or other biomarkers, to better understand the physiological underpinnings of anxiety in this population.

Stress was also significantly negatively correlated with HRV parameters, including SDNN, RMSSD, SDANN, VLF, and LF. These results suggest that higher HRV is associated with greater resilience to stress, as supported by prior research [7], [17]. Notably, stress responses in this population may be influenced by factors such as workload, emotional demands, and the need for rapid decision-making in critical situations [21]. As anesthesiology residents often face high-pressure environments, interventions aimed at improving stress resilience, such as mindfulness-based training or biofeedback, could be beneficial in maintaining both mental and physiological health [22].

6. Conclusion

In conclusion, this study highlights significant associations between depression and stress with HRV parameters, underscoring the potential of HRV as a biomarker for monitoring psychological health in high-demand clinical settings. These findings emphasize the importance of proactive mental health support and stress management programs tailored to the unique needs of anesthesiology residents.

Limitation

The study has limitations due to cross-sectional design and small sample size. This could affect the ability to draw causal inferences and limit the generalizability of the findings. Additionally, external factors such as sleep patterns, physical activity, and dietary habits were not controlled, potentially influencing HRV measurements. Future studies should adopt longitudinal designs and integrate multimodal assessments, including hormonal or biochemical biomarkers, to gain a deeper insight into the interconnection between HRV and psychological stress in anesthesiology residents.

Conflicts of Interest

The author states that they do not have any personal or financial conflicts that could influence their work.

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