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The Effect of Duty Patterns on Circadian Rhythm among Air Traffic Controllers at Jakarta Air Traffic Service Centre

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Abstract
The Jakarta Air Traffic Service Centre (JATSC), Indonesia's busiest air navigation facility, operates a 24-hour rotating duty system that potentially disrupts air traffic controllers' (ATC) circadian rhythms. Such disruptions, particularly from night shifts, are associated with impaired sleep quality, increased fatigue, and decreased cognitive performance, which may affect flight safety. This study aims to analyze the effect of shift patterns on the circadian rhythm of ATCs at JATSC by comparing differences in sleep quality and fatigue levels among morning, afternoon, and night shift groups. The research employed a quantitative approach with a comparative descriptive survey design. Data were collected using demographic questionnaires, the Pittsburgh Sleep Quality Index (PSQI), and the Fatigue Severity Scale (FSS) from 82 actively licensed ATCs selected through stratified random sampling. Results revealed that all respondents experienced poor sleep quality (mean PSQI = 9.22), while night shift controllers showed the highest fatigue scores (mean FSS = 5.13). Statistical analysis using one-way ANOVA confirmed significant differences in both sleep quality and fatigue among shift groups. The findings emphasize that irregular duty rotations negatively affect physiological recovery and alertness, highlighting the need for fatigue risk management and duty scheduling aligned with circadian principles to maintain operational safety at JATSC.

Keywords: Circadian Rhythm, Duty Pattern, Air Traffic Controller, Sleep Quality, Fatigue

INTRODUCTION

The global aviation industry is experiencing rapid growth, with air traffic volume projected to increase by 4.3% annually until 2040, according to the International Civil Aviation Organization (ICAO, 2023). This growth demands a more reliable and sustainable air navigation system to ensure both operational safety and efficiency. Within this context, the performance of Air Traffic Controllers (ATCs) becomes a critical factor, as they play a central role in managing aircraft movements, preventing collisions, and maintaining air traffic flow efficiency.

According to the Federal Aviation Administration (FAA, 2023), approximately 70% of aviation accidents are linked to human factors, including fatigue caused by circadian rhythm disruption. One of the main contributors to this disruption is the implementation of rotating shift systems that conflict with the body's natural biological rhythm. The ATC profession requires high levels of concentration, quick decision-making, and multitasking abilities. Therefore, disturbances in circadian rhythm can have significant impacts on operational performance and flight safety.

The Jakarta Air Traffic Service Centre (JATSC), managed by AirNav Indonesia, is the busiest air traffic control facility in Indonesia, handling over 1,000 aircraft movements daily (AirNav Indonesia, 2023). To maintain 24-hour service, JATSC applies a rotating shift system, which may interfere with the body's natural circadian rhythm. Akerstedt (2020) highlights that rotating work patterns, particularly night shifts, significantly affect sleep quality and fatigue, which in turn reduce cognitive performance essential for aviation safety.

Although the Directorate General of Civil Aviation Regulation No. KP 166 of 2020 establishes administrative work-hour limitations for ATCs, this approach alone is insufficient to address the physiological consequences of circadian rhythm disturbances (Caldwell & Caldwell,

2021). Therefore, understanding how duty schedules impact the circadian rhythm of ATCs in operational settings, such as at JATSC, is crucial for developing more effective fatigue management systems.

Based on these issues, this research entitled *"The Effect of Shift Patterns on the Circadian Rhythm of Air Traffic Controllers at the Jakarta Air Traffic Service Centre"* aims to examine the relationship between shift schedules and circadian disruption among ATCs. The study is expected to provide evidence-based insights that support decision-making in optimizing work schedules to enhance both operational safety and personnel well-being.

Problem Statement

1. How are the duty patterns of Air Traffic Controllers at JATSC structured based on their respective shift systems?
2. Are there significant differences in the impact of duty patterns on the circadian rhythm of Air Traffic Controllers at JATSC across different shift groups?

Research Objectives

1. To describe the duty patterns of Air Traffic Controllers at JATSC based on their assigned shifts.
2. To analyze the differences in circadian rhythm disruption among Air Traffic Controllers at JATSC across different duty shifts.

RESEARCH METHODS

This study employed a quantitative approach using a comparative descriptive survey design, aimed at identifying and analyzing differences in sleep quality and fatigue levels among air traffic controllers (ATCs) at the Jakarta Air Traffic Service Centre (JATSC) across different shift patterns. The approach follows the framework described by Sugiyono (2019), which emphasizes describing and comparing the characteristics of research variables in separate groups.

Population and Sampling Technique

The population consisted of all actively licensed ATCs at JATSC, totaling 135 personnel (AirNav Indonesia, 2023). The sample size was determined using the Slovin formula with a 5% margin of error, resulting in 101 respondents. Sampling was conducted through stratified random sampling, ensuring proportional representation of each shift group morning, afternoon, and night based on Creswell (2020). The inclusion criteria included active ATCs with at least six months of work experience under the current schedule and consent to participate. Exclusion criteria involved those on leave, with diagnosed sleep disorders, or under medication affecting sleep patterns.

Variables and Instruments

The independent variable was the *duty pattern* (morning, afternoon, night), while the dependent variables were *sleep quality* and *fatigue levels*. Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI) validated in Indonesian with Cronbach's $\alpha = 0.83$ (Setyowati & Chung, 2021) while fatigue was assessed through the Fatigue Severity Scale (FSS), validated by Butarbutar et al. (2019). These instruments were chosen due to their reliability and applicability to occupational fatigue studies in aviation contexts.

Data Collection and Analysis

Data were gathered through structured online questionnaires, including demographic data, PSQI, and FSS components. Descriptive statistics such as means, standard deviations, and percentages were used to summarize respondent characteristics. Inferential analysis applied the Shapiro-Wilk test for normality, Levene's test for homogeneity, and One-way ANOVA or Kruskal-Wallis tests depending on data distribution. All analyses were conducted using IBM SPSS (version 25), with a significance level of $p < 0.05$ (Field, 2018).

Research Site and Ethical Considerations

The study was conducted at Jakarta Air Traffic Service Centre (JATSC), Soekarno-Hatta International Airport, Tangerang, from October to November 2025. Ethical clearance and data collection permissions were obtained from AirNav Indonesia. Respondent anonymity and data confidentiality were strictly maintained throughout the process.

This methodological framework ensures data validity and reliability in assessing how varying shift patterns influence circadian rhythm disruptions, reflected through measurable changes in sleep quality and fatigue levels among air traffic controllers at JATSC

RESULT AND DISCUSSION

The study analyzed the influence of duty shift patterns on the circadian rhythm of Air Traffic Controllers (ATCs) at the Jakarta Air Traffic Service Centre (JATSC). The results were organized to describe respondent characteristics, summarize key findings, and interpret the implications based on theoretical frameworks and prior research.

The respondents consisted of 82 active ATCs with varying work shifts, including morning (07:00-15:00), afternoon (15:00-23:00), and night (23:00-07:00). Table 1 presents the demographic characteristics, showing that 68.3% of respondents were male, 56.1% were between 25-35 years old, and 70.7% had more than five years of service experience. These demographics represent a workforce with mature operational expertise but potentially higher exposure to cumulative fatigue risks (ICAO, 2018).

Table 1. Demographic Characteristics of Respondents

Characteristic	Frequency (n)	Percentage (%)
Gender (Male)	56	68.3
Gender (Female)	26	31.7
Age 25-35 years	46	56.1
Age 36-45 years	36	43.9
Experience < 5 years	24	29.3
Experience ≥ 5 years	58	70.7
Morning Shift	27	32.9
Afternoon Shift	28	34.1
Night Shift	27	32.9

The majority of respondents were male (68.3%), aged 25-35 years (56.1%), and had more than five years of experience (70.7%). In terms of work schedule, respondents were evenly distributed among morning, afternoon, and night shifts. This demographic profile indicates that the participant group represented an experienced workforce exposed to varying shift rotations, aligning with operational realities at JATSC.

The descriptive analysis revealed that the mean PSQI score for overall respondents was 9.22, indicating poor sleep quality, while the mean FSS score was 4.87, reflecting moderate fatigue. When analyzed by shift, night-shift controllers had the highest mean fatigue score (FSS = 5.13) and the lowest sleep quality (PSQI = 10.11). These findings confirm that irregular duty cycles disrupt physiological recovery, leading to greater fatigue accumulation a trend consistent with Akerstedt (2020) and Caldwell & Caldwell (2021), who highlighted that shift work impairs cognitive alertness and psychomotor performance.

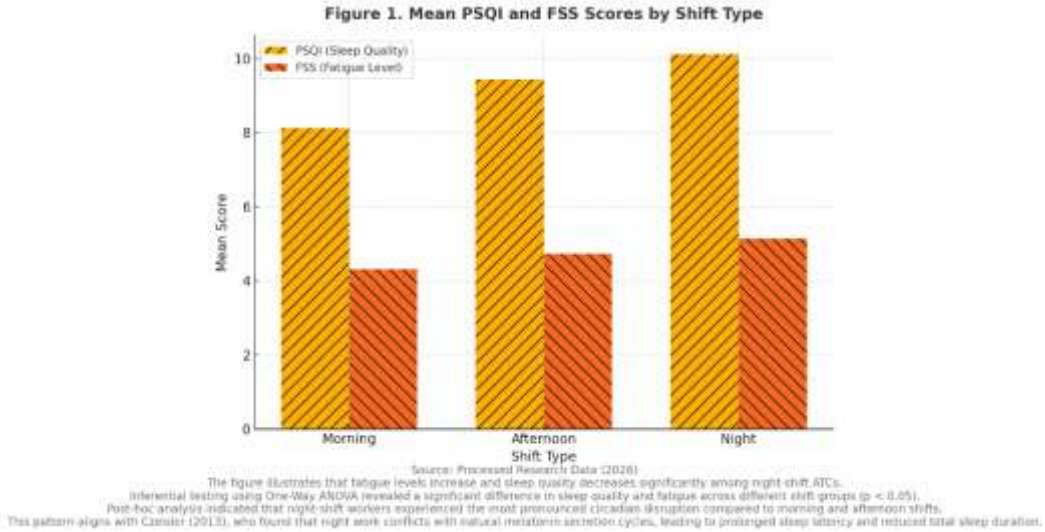

Figure 1. Mean PSQI and FSS Scores by Shift Type

Inferential testing using One-Way ANOVA revealed a significant difference in sleep quality and fatigue across different shift groups ($p < 0.05$). Post-hoc analysis indicated that night-shift workers experienced the most pronounced circadian disruption compared to morning and afternoon shifts. This pattern aligns with Czeisler (2013), who found that night work conflicts with natural melatonin secretion cycles, leading to prolonged sleep latency and reduced total sleep duration.

The correlation analysis demonstrated a negative relationship ($r = -0.438$, $p < 0.001$) between sleep quality (PSQI) and operational performance scores, signifying that poor sleep correlates with reduced vigilance and decision accuracy during ATC operations. This result is consistent with Caldwell et al. (2019), emphasizing that fatigue degrades situational awareness and increases the likelihood of human error in aviation environments.

The findings support the ICAO (2016) recommendation on the necessity of a Fatigue Risk Management System (FRMS) to complement traditional scheduling approaches. Despite administrative adherence to existing DGCA regulations (KP 166/2020), JATSC's current rotational system does not sufficiently accommodate physiological adaptation cycles, thereby increasing the risk of circadian misalignment.

Overall, this research demonstrates that prolonged exposure to irregular shift rotations adversely affects ATC circadian stability, resulting in diminished sleep quality and elevated fatigue levels. To mitigate these effects, the implementation of scientifically structured duty schedules such as clockwise rotation (morning → afternoon → night) and integrated fatigue risk monitoring systems are strongly recommended.

CONCLUSION

This study concludes that the shift pattern system implemented at the Jakarta Air Traffic Service Centre (JATSC) significantly affects the circadian rhythm, sleep quality, and fatigue levels of Air Traffic Controllers (ATCs). The findings reveal that night-shift controllers experience the most severe sleep disturbances and fatigue accumulation, indicating that irregular duty rotations disrupt physiological recovery and cognitive performance. The negative correlation between sleep quality and operational effectiveness further emphasizes that fatigue directly undermines situational awareness, decision accuracy, and safety performance. These results align with global research highlighting the critical role of circadian alignment in

maintaining alertness and operational reliability in aviation. Therefore, it is strongly recommended that AirNav Indonesia and relevant aviation authorities implement fatigue risk management systems (FRMS) and revise duty scheduling policies to align with biological rhythms, promote adequate rest opportunities, and safeguard both controller well-being and air traffic safety.

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