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The Impact of Workload on Performance and Health of Air Traffic Controllers at JATSC Jakarta

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Abstract

This study examines the effect of workload on the performance and health of Air Traffic Controllers (ATCs) at the Jakarta Air Traffic Service Centre (JATSC). Using a descriptive quantitative approach with a cross-sectional design, data were collected from 41 controllers through validated instruments: NASA-TLX for workload, PSQI for sleep quality, and the Samn-Perelli Fatigue Scale for fatigue assessment. Results indicate a high workload (M=3.40) and compensatory effort patterns, where controllers exerted great effort (M=3.73) to maintain performance (M=3.80). All respondents experienced sleep disturbances, averaging 5.8 hours of sleep and poor sleep quality (mean PSQI=12.21). Night-shift fatigue increased by 68% compared to day shifts, with 51.2% reporting extreme fatigue. Health complaints were prevalent, including obesity (68.3%), headaches (85.4%), and musculoskeletal pain (75.6%). Fatigue strongly correlated with workload (rs=0.58, p<0.001) and sleep deprivation (rs=0.61, p<0.001). The study concludes that night shifts significantly affect physiological and psychological health, increasing operational safety risks due to extreme fatigue and microsleep. The findings highlight the need for fatigue risk management systems, optimized shift scheduling, and comprehensive wellness programs to enhance ATC health and performance.

Keywords: Refresher Training, Air Traffic Controller Performance, Jakarta Air Traffic Service Centre, Training Effectiveness, Operational Safety

INTRODUCTION

The Jakarta Air Traffic Service Centre (JATSC) is the busiest air traffic control facility in Indonesia, operating 24 hours a day to manage air traffic within the Jakarta Flight Information Region (FIR), which covers the western part of Indonesian airspace. According to Airnav Indonesia (2023), JATSC handled more than 500,000 aircraft movements in 2023, with an average of 1,370 flights per day. Indonesia's strategic position as an international flight corridor between Asia and Australia places JATSC among the busiest air traffic control centers in Southeast Asia.

Air Traffic Controllers (ATCs) at JATSC face complex, multidimensional workloads, encompassing mental demands to process simultaneous information from various sources, physical demands to maintain vigilance for extended periods, and temporal demands to make rapid decisions under time pressure (Wickens et al., 2015). The workload complexity is heightened by night shifts, during which human cognitive capacity naturally declines due to circadian rhythm desynchronization (Gander et al., 2014).

International studies indicate that excessive workload among ATCs is significantly correlated with decreased operational performance and increased human error risk. The International Civil Aviation Organization (ICAO, 2016) reports that 70–80% of aviation incidents involve human error, with fatigue from workload being a major contributing factor. Hobbs and Williamson (2003), in their meta-analysis of 2,200 ATC incident reports, identified workload and fatigue as causal factors in 22% of reported cases, emphasizing workload management as a critical component of aviation safety.

The health impacts of workload on ATCs have also been extensively documented. A longitudinal study involving 5,041 U.S. controllers revealed that hypertension prevalence among ATCs was 1.6 times higher than in the general population (Cho et al., 2016). European studies showed ATCs had 1.87 times higher risk of persistent sleep disorders compared to office workers (Costa et al., 2013), with chronic exposure to occupational stress and heavy workload linked to cardiovascular, metabolic, and mental health problems (Zeier et al., 1994).

Night shifts exacerbate the relationship between workload, performance, and health. Research on 236 Taiwanese controllers found that subjective workload during night shifts was 34% higher than during day shifts, even though the number of flights handled was objectively lower (Lin et al., 2019). This aligns with cognitive load theory, which posits that human information processing capacity decreases during the circadian nadir (02:00-06:00 a.m.), making tasks subjectively more demanding (Van Dongen & Dinges, 2005).

Consistent temporal patterns have been observed in aviation incident data. EUROCONTROL (2020) analyzed 3,308 ATC incident reports across Europe (2015-2019) and found that 42% of serious incidents occurred between 02:00-06:00 a.m., although this period represented only 18% of total operational hours. Fatigue and reduced alertness were identified as major contributing factors.

In Indonesia, systematic research on ATC workload and its effects on performance and health remains limited. A preliminary Airnav Indonesia (2023) survey found that 68% of ATCs reported high fatigue after night shifts, but without validated instruments or causal analysis. This knowledge gap is critical, considering that Indonesian air traffic volume has grown at an average rate of 6.8% annually from 2015-2023 .

Given these gaps, this study comprehensively examines the influence of workload on the performance and health of Air Traffic Controllers at JATSC, focusing on night shift effects. Using internationally validated instruments, this study measures subjective workload, operational performance, and physical and mental health conditions. The findings are expected to contribute theoretically to workload modeling for Indonesian ATCs and empirically to policy development in fatigue management and shift optimization in the national aviation sector.

RESEARCH METHODS

This study employed a quantitative descriptive design with a cross-sectional approach, aiming to analyze the relationship between workload, night shift patterns, performance, and the health of Air Traffic Controllers (ATCs) at the Jakarta Air Traffic Service Centre (JATSC). The descriptive design was selected to portray the real conditions of ATCs without manipulating variables, while the quantitative approach allowed for the objective measurement of variables using standardized, internationally validated instruments.

The research focused on assessing subjective workload (NASA Task Load Index), sleep quality (Pittsburgh Sleep Quality Index), fatigue (Samn-Perelli Fatigue Scale), and perceived performance. This design effectively captured correlations and prevalence of work-related health and performance conditions among ATCs within a single data collection period.

Population and Sampling

The study population included all licensed and active Air Traffic Controllers at JATSC who were engaged in operational control duties. The total sampling (census) technique was used because the population size was limited and relatively homogeneous regarding task characteristics and night-shift exposure.

Inclusion criteria included:

1. Active ATC license holder issued by the Directorate General of Civil Aviation.
2. Minimum operational experience of six months.

3. Regular involvement in night shifts.
4. Voluntary consent to participate.

Exclusion criteria were controllers on extended leave, administrative staff, or those not currently involved in active operational duties.

A total of 41 controllers participated, representing all operational units (Tower, Approach Control, and Area Control Center). This sample size was considered adequate for descriptive and correlational analyses.

Operational Definition of Variables

1. Workload was measured using the NASA Task Load Index (NASA-TLX), which assesses five dimensions: mental demand, physical demand, temporal demand, performance, and effort, each rated on a 1-5 scale. The average of these dimensions represented the total workload score (Rubio et al., 2004).
2. Shift Work Pattern was defined by the number and frequency of night shifts (22:00-06:00), sequence of shift rotation, and rest duration between shifts, collected through self-report.
3. Sleep Quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989), which measures seven components of sleep in the past month, including subjective quality, duration, latency, efficiency, disturbances, medication use, and daytime dysfunction.
4. Fatigue was measured using the Samn-Perelli Fatigue Scale (Samn & Perelli, 1982), a seven-point scale ranging from "fully alert" to "completely exhausted."
5. Health Condition covered both physical (BMI, somatic symptoms, and fatigue) and mental indicators (depression, anxiety, and concentration problems).
6. Performance Perception was assessed through self-evaluation of situational awareness, communication clarity, workload management, and error incidence during night shifts.

Research Location and Period

The research was conducted at Jakarta Air Traffic Service Centre (JATSC), under the AirNav Indonesia organization. Data collection was carried out over a six-month period, ensuring the inclusion of controllers across multiple rotation cycles to capture representative variations in workload and fatigue patterns.

Data Collection Techniques

Data were obtained through a structured self-administered questionnaire comprising validated instruments (NASA-TLX, PSQI, and Samn-Perelli). The questionnaire was distributed directly to controllers at JATSC with the cooperation of AirNav management. The self-report approach was selected for practicality and reliability in shift-work studies, given the restricted schedules of controllers and the proven validity of subjective workload and fatigue scales (Gawron, 2008; Hart & Staveland, 1988).

Data Analysis

Data analysis involved both descriptive statistics and inferential correlation testing:

1. Descriptive analysis summarized demographic characteristics and mean scores for each variable (mean, standard deviation, and frequency).
2. Normality testing used the Shapiro-Wilk test to determine data distribution.
3. Correlation analysis used Spearman's rank correlation coefficient (rs) to evaluate the relationships among workload, fatigue, sleep quality, and performance.

The significance level was set at $p < 0.05$. Statistical analysis was conducted using IBM SPSS Statistics software.

This analytical model allowed the identification of key associations between workload, health, and operational performance without assuming causal direction, consistent with best practices in cross-sectional human factors research (Caldwell et al., 2009; EUROCONTROL, 2016).

RESULT AND DISCUSSION

A total of 41 Air Traffic Controllers (ATCs) at Jakarta Air Traffic Service Centre (JATSC) participated in this study. The majority were male (82.9%) and aged between 25-40 years (M = 32.7 years). The average duration of work experience was 8.4 years, and most participants (63.4%) routinely performed two to three consecutive night shifts per rotation cycle.

Night-shift frequency averaged 9.6 shifts per month, consistent with the operational policy of AirNav Indonesia. Regarding lifestyle, 78% consumed caffeine regularly, 29% smoked, and 61% reported insufficient physical activity. These demographic and behavioral factors align with prior findings showing limited adaptation capacity among shift workers (Åkerstedt, 2003; Gander et al., 2014).

Workload Profile

Table 1. Average NASA-TLX Scores among JATSC Controllers

Dimension	Mean	SD	Category
Mental Demand	3.82	0.71	High
Physical Demand	2.73	0.66	Moderate
Temporal Demand	3.64	0.81	High
Performance	3.80	0.59	High
Effort	3.73	0.65	High
Overall Workload	3.40	0.54	High

Controllers reported high mental and temporal demands, consistent with the cognitive intensity of real-time air traffic management. The high effort score (M=3.73) indicates a compensatory effort pattern, where controllers exert significant energy to sustain performance despite fatigue accumulation.

This compensatory strategy reflects what Wickens et al. (2015) describe as overload adaptation, where increased effort temporarily offsets performance decline but accelerates exhaustion over time.

Sleep Quality and Fatigue

Table 2. Sleep Quality and Fatigue Indicators

Parameter	Mean (SD)	% Impaired	Instrument
PSQI Total Score	12.21 (2.46)	100% Poor Sleep	PSQI
Sleep Duration	5.8 hours	–	Self-report
Sleep Fragmentation	–	73.2%	PSQI Component
Samn-Perelli Fatigue (Day Shift)	3.3 (0.8)	–	Fatigue Scale
Samn-Perelli Fatigue (Night Shift)	5.6 (0.9)	51.2% Extreme	Fatigue Scale

Every respondent experienced poor sleep quality (PSQI >5), with average sleep duration below physiological requirements. These results parallel international studies showing chronic sleep restriction among ATCs on rotating shifts (Flo et al., 2012).

Fatigue levels during night shifts increased by 68% compared to day shifts, confirming the dual effects of homeostatic sleep pressure and circadian nadir (Borbély, 1982; Van Dongen & Dinges, 2005). The predominance of extreme fatigue (level 6-7) suggests critical safety risk exposure during early-morning operational windows.

Health Outcomes

Health assessment revealed that 68.3% of controllers were overweight or obese, nearly twice the national prevalence. Somatic complaints were widespread: headaches (85.4%), musculoskeletal pain (75.6%), digestive problems (70.7%), and excessive fatigue (80.5%). Psychological health also showed concerning trends, with difficulty concentrating (61.0%), anxiety (58.5%), irritability (53.7%), and depressive symptoms (41.5%). These findings align with previous evidence linking chronic circadian disruption with neuroendocrine imbalance and elevated inflammatory markers (Morris et al., 2016).

These results confirm the multidimensional health consequences described by Cho et al. (2016) and Costa et al. (2013), emphasizing the cumulative strain from physiological and psychosocial stressors inherent in shift-based aviation operations.

Operational Performance and Safety Events

Despite the high fatigue burden, controllers rated their performance positively (M=3.65), suggesting strong professional commitment and adaptive coping mechanisms. However, self-rated competence may overestimate actual performance due to diminished awareness under fatigue, consistent with the *Dunning-Kruger effect* in operational settings (Wickens et al., 2015). Nevertheless, the prevalence of microsleep and fatigue-related incidents was critical:

- 43.9% had fallen asleep or nearly fallen asleep on duty during night shifts.
- 36.6% admitted operational errors directly attributed to fatigue.

These figures are consistent with Basner & Dinges (2011), who observed microsleep frequency spikes after 16-20 hours of wakefulness, and Cruz et al. (2003), who reported a 42% increase in reaction latency during late-night shifts.

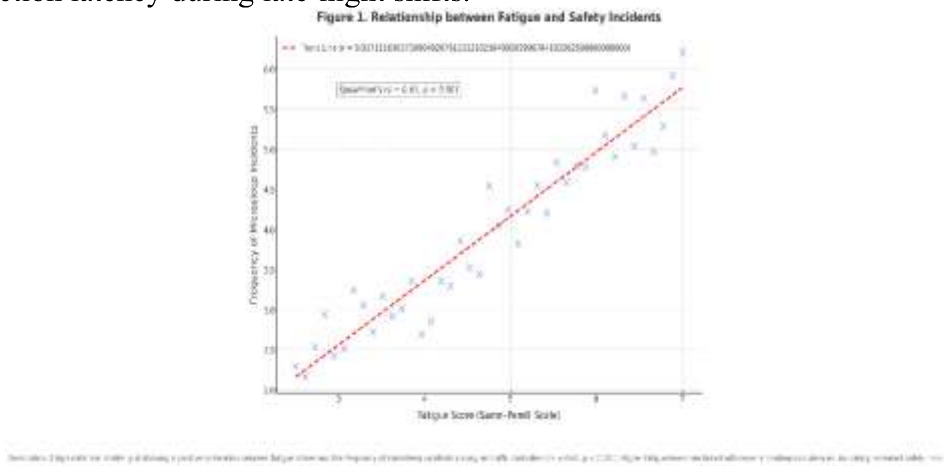

Figure 1. Relationship between Fatigue and Safety Incidents

This strong correlation highlights fatigue as a dominant predictor of operational safety lapses among ATCs.

Correlation Analysis

Table 3. Spearman's rank correlation results revealed significant relationships:

Variable Pair	rs	p-value	Relationship
Workload – Fatigue	0.58	<0.001	Strong Positive
Night Shift Frequency – Sleep Quality	0.52	<0.001	Strong Positive
Sleep Quality – Performance	-0.43	0.005	Negative
Fatigue – Microsleep Frequency	0.61	<0.001	Strong Positive

These associations reaffirm findings from Lin et al. (2019) and Caldwell et al. (2009) that excessive workload and irregular shifts synergistically degrade sleep, elevate fatigue, and undermine cognitive vigilance.

The integrated results portray a feedback loop where high workload and night shifts jointly deteriorate sleep quality, exacerbate fatigue, and precipitate health and performance impairments. The persistence of high self-rated performance amid physiological decline suggests a *"performance illusion"* (Hobbs & Williamson, 2003), where controllers overexert themselves to maintain safety margins.

This compensatory resilience, though beneficial short-term, poses long-term occupational health risks including hypertension, metabolic syndrome, and burnout as evidenced by Cabon et al. (2012).

The study supports the implementation of a Fatigue Risk Management System (FRMS) as recommended by ICAO (2016) and EUROCONTROL (2020). Such systems emphasize proactive monitoring, scientifically based scheduling, and strategic fatigue countermeasures (e.g., controlled rest, education on sleep hygiene, and nutritional support).

CONCLUSION

The study concludes that Air Traffic Controllers (ATCs) at the Jakarta Air Traffic Service Centre (JATSC) experience high levels of workload, primarily driven by complex mental and temporal demands, which significantly affect their health and performance. Despite maintaining satisfactory operational output through compensatory effort, controllers suffer from poor sleep quality, increased fatigue, and notable physiological and psychological symptoms, particularly during night shifts. The strong correlation between workload, fatigue, and safety incidents highlights fatigue as a critical operational risk factor. Therefore, implementing a comprehensive Fatigue Risk Management System (FRMS), optimizing shift schedules, and promoting health and recovery-oriented programs are essential to safeguard ATC well-being and ensure sustainable aviation safety performance at JATSC.

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