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ORIGINAL

Analysis of The Determinants of Work Fatigue in Aircraft Maintenance Engineers at Sultan Hasanuddin International Airport Makassar

Análisis de los factores determinantes de la fatiga laboral en los ingenieros de mantenimiento de aeronaves del Aeropuerto Internacional Sultan Hasanuddin de Makassar

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ABSTRACT

Introduction: occupational Safety and Health (OSH) is important to prevent accidents and fatigue experienced by 32,8 % of workers, while in the aviation industry, the shortage of technicians and 24-hour shift work system increases the risk of fatigue that impacts the safety and quality of aircraft maintenance.
Method: this research is an analytical observational study with a cross sectional quantitative approach to 106 of 145 Aircraft Maintenance Engineers at Sultan Hasanuddin International Airport Makassar, using KAUPK2, NASA-TLX, PSQI questionnaires, as well as pulse oximeter and BMI measuring instruments, with chi-square analysis and logistic regression through SPSS.
Results: the results showed a significant relationship between several variables with work fatigue, namely age (p=0,001) tenure (p=0,002) smoking habits (p=0,000), sleep quality (p=0,002) marital status (p=0,000) physical workload (p=0,000) and mental workload (p=0,008). The logistic regression model proved feasible (p=0,000) and was able to explain 47,6 % of the variation in work fatigue, with the most influential variables being age, marital status, physical workload, and smoking habits.
Conclusion: this study concludes that job burnout in Aircraft Maintenance Engineers is significantly influenced by age, smoking habits, physical workload, and marital status, thus workload management, quality of life improvement, and work-family balance support need to be prioritized.

Keywords: Job Burnout; Aircraft Maintenance Engineer; Physical Workload; Smoking Habit; Marital Status.

RESUMEN

Introducción: la seguridad y la salud en el trabajo (SST) es importante para prevenir los accidentes y la fatiga que sufre el 32,8 % de los trabajadores, mientras que en el sector de la aviación, la escasez de técnicos y el sistema de turnos de 24 horas aumentan el riesgo de fatiga, lo que repercute en la seguridad y la calidad del mantenimiento de las aeronaves.
Método: esta investigación es un estudio observacional analítico con un enfoque cuantitativo transversal de 106 de los 145 ingenieros de mantenimiento de aeronaves del Aeropuerto Internacional Sultan Hasanuddin de Makassar, utilizando los cuestionarios KAUPK2, NASA-TLX y PSQI, así como pulsómetros y medidores de IMC, con análisis de chi-cuadrado y regresión logística mediante SPSS.
Resultados: los resultados mostraron una relación significativa entre varias variables y la fatiga laboral, a saber, la edad (p = 0,001), la antigüedad (p = 0,002), el tabaquismo (p = 0,000), la calidad del sueño (p = 0,002), el estado civil (p = 0,000), la carga de trabajo físico (p = 0,000) y la carga de trabajo mental (p = 0,008). El modelo

de regresión logística resultó viable (p=0,000) y fue capaz de explicar el 47,6 % de la variación en la fatiga laboral, siendo las variables más influyentes la edad, el estado civil, la carga de trabajo físico y los hábitos de tabaquismo.
Conclusión: este estudio concluye que el agotamiento laboral de los ingenieros de mantenimiento de aeronaves está significativamente influenciado por la edad, los hábitos de tabaquismo, la carga de trabajo físico y el estado civil, por lo que es necesario dar prioridad a la gestión de la carga de trabajo, la mejora de la calidad de vida y el apoyo al equilibrio entre el trabajo y la familia.

Palabras clave: Agotamiento Laboral; Ingeniero de Mantenimiento de Aeronaves; Carga de Trabajo Físico; Hábito de Fumar; Estado Civil.

INTRODUCTION

Occupational Safety and Health (OSH) is an important effort to protect workers from risks and hazards in the workplace through the implementation of regulations and policies that ensure a safe, healthy, and productive work environment.[1] According to the International Labour Organization, more than 2,78 million workers die each year from occupational accidents and diseases, with 374 million injured and about 32,8 % of 58,115 workers experiencing fatigue which increases the risk of accidents and decreases work productivity.[2] Human factors such as sleep problems and fatigue greatly affect work productivity, as evidenced by the increasing cases of work accidents in Indonesia from 210,789 cases in 2019 to 234,370 cases in 2021, while research by WHO and the Japanese Ministry of Labor shows that fatigue is the second killer disease after heart disease, with 65 % of workers experiencing physical fatigue, 28 % mental fatigue, and 7 % severe stress.[3]

Occupational fatigue, which is influenced by internal and external factors such as age, sleep quality, and workload, is a major cause of work accidents, with research at PT X Palembang showing 75 % of workers aged ≥40 years experienced high fatigue compared to 85,7 % of workers <40 years with low fatigue (4). A working life of more than 5 years increases the risk of chronic fatigue, with 50 % of highly experienced workers experiencing fatigue, while poor sleep quality experienced by 20-40 % of adults decreases health, focus and productivity, and increases the risk of occupational fatigue.[5]

Workload is the difference between a worker's ability and the demands of the job, which includes physical load due to muscle activity as well as mental load due to the use of the mind, the balance between the two is important as sustained overload can increase the risk of fatigue, illness and occupational accidents.[6] Marital status is also a confounding factor that needs to be considered in relation to occupational fatigue. Married workers are found to be more prone to occupational fatigue compared to unmarried workers. This is due to a change in lifestyle in married workers, who cannot be as active as before marriage.

The habit of smoking reduces lung capacity and oxygen in the blood thus accelerating job fatigue, while the rapid growth of Indonesia's air transportation sector with 285 airports and more than 75 million passengers per year demands increased safety and efficiency in accordance with Law Number 1 of 2009.[7] In the aviation industry, human error in maintenance accounts for 20-30 % of engine failures, 50 % of delays, and 50 % of flight cancellations, while in Indonesia, the limitations of MRO companies and the lack of technicians-only 200-300 of the required 1,000 per year-increases the workload and risk of fatigue in aviation personnel. Aircraft Maintenance Engineers (AMEs) are aircraft technicians who ensure airworthiness through inspection and maintenance, but the 24-hour shift work system and high workload can cause fatigue that affects productivity, safety and health.[8]

The work of aircraft engineers falls into the high-risk category, as it involves great risk and long working hours. High working hours, which are not proportional to the number of technicians available, cause many accidents experienced by workers. This is not only detrimental to the workers themselves, but can also lead to huge financial losses and potentially fatal flight failures.[9] Accidents that occur in the aviation sector are not immune to occupational accidents that can be experienced by technician workers when carrying out aircraft maintenance and repairs.[10] Aircraft technician fatigue is a major contributing factor to maintenance errors because it reduces concentration, reaction speed, and decision-making ability, thus having a direct impact on flight safety. Therefore based on the background described, this study aims to determine the influence of the determinants of work fatigue (age, tenure, sleep quality, physical workload, mental workload, marital status, and smoking habits) on Aircraft Maintenance Engineer of Sultan Hasanuddin International Airport Makassar.

METHOD

This study employed an analytical observational design with a quantitative cross-sectional approach to analyze the influence of age, tenure, sleep quality, physical workload, mental workload, marital status, and smoking habits on job fatigue among Aircraft Maintenance Engineers (AMEs) at Sultan Hasanuddin International

Airport, Makassar, conducted from July 14 to August 26, 2025. The population consisted of 145 AMEs (36 from Company A and 109 from Company B). Based on the Slovin formulawith an error margin of 5 % (e = 0,05) 106 respondents were selected using a simple random sampling technique. Participants included active AMEs with at least six months of work experience who were willing to participate and signed informed consent. Those who were on leave, sick, or provided incomplete data were excluded. The dependent variable was work fatigue, while the independent variables included age, tenure, sleep quality, physical and mental workload, marital status, and smoking habits. Work fatigue was measured using the KAUPK2 questionnaire, mental workload with the NASA Task Load Index (NASA-TLX), sleep quality using the Pittsburgh Sleep Quality Index (PSQI), and physical workload through physiological measurements (heart rate) using a pulse oximeter.

All instruments used have been validated in previous studies and are reliable for occupational health research in Indonesia. Primary data were collected directly from respondents through questionnaires and physiological measurements, while secondary data were obtained from journals, books, official websites, and internal company records. Data processing used the SPSS program, beginning with editing, coding, data entry, and cleaning. Analyses were conducted univariately to describe variables, bivariately using the Chi-square test to examine relationships, and multivariately with logistic regression to identify the most influential factors on work fatigue, with a significance level of $p < 0,05$. This research followed ethical principles of respect, beneficence, and justice. Ethical approval was granted by the Health Research Ethics Committee, Hasanuddin University, Makassar, under Ethical Clearance Number: 920/UN4.14.1/TP.01.02/2025. All respondents were informed about the purpose and procedures of the study, and confidentiality of their data was strictly maintained.

RESULTS

Table 1. Characteristics of Respondents

Variable	Category	Number (n)	Percentage (%)
Age	17-25 years old	7	6,6
	26-35 years old	61	57,5
	36-45 years old	31	29,2
	46-55 years	5	4,7
	56-65 years	2	1,9
Last Education	High School/Vocational School	35	33,0
	Diploma	54	50,9
	S1	15	14,2
	S2	2	1,9
Period of Employment	< 6 years	17	16,0
	6-10 years	36	34,0
	> 10 years	53	50,0
Marital Status	Married	78	73,6
	Unmarried	28	26,4
Smoking Habit	Heavy	43	40,6
	Moderate	25	23,6
	Mild	13	12,3
	No Smoking	25	23,6
Sleep Quality	Good	18	17,0
	Poor	88	83,0
Physical Workload	Mild	55	51,9
	Heavy	51	48,1
Mental Workload	Light	33	31,1
	Moderate	45	42,5
	High	28	26,4
Work Fatigue	Less Fatigued	43	40,5
	Tired	41	38,7
	Very Tired	22	20,8

This study was conducted on 106 Aircraft Maintenance Engineers from Company A and B which are engaged in Maintenance, Repair, and Overhaul (MRO) of aircraft at Sultan Hasanuddin International Airport Makassar. Both companies have an important role in maintaining flight safety with a rotating work system, strict time targets, and high safety standards that have the potential to cause job burnout. Engineers in both companies can be assigned to various cities according to the aircraft license and are required to renew the AMEL (Aircraft Maintenance Engineer License) every two years. This study was conducted because these high-risk jobs are influenced by age, tenure, sleep quality, workload, marital status, and smoking habits that have the potential to cause fatigue. The results of the study of 106 Aircraft Maintenance Engineers at Sultan Hasanuddin International Airport Makassar in 2025 showed the majority were aged 26-35 years (57,5 %), had a Diploma education (50,9 %), were married (73,6 %), and had a work period of more than 10 years (50 %) with 83 % experiencing poor sleep quality. The high level of fatigue 38,7 % tired and 20,8 % very tired, was influenced by age, long working life, smoking (59,4 %) and poor sleep quality.

Table 2. Influence between Age and Occupational Fatigue in Aircraft Maintenance Engineers

Age	Work Fatigue						Total		P-value
	Very Tired		Tired		Less Tired				
	n	%	n	%	n	%	n	%	
Old	7	18,4	23	60,5	8	21,1	38	100	0,001
Young	15	22,1	18	26,5	35	51,5	68	100	
Total	22	20,8	41	38,7	43	40,6	106	200	

Results showed a significant association between age and fatigue (p = 0,001) with older workers experiencing higher fatigue (60,5 %) than younger workers (26,5 %). This suggests that increasing age has an effect on decreasing endurance and increasing occupational fatigue.

Table 3. Effect of Length of Service on Occupational Fatigue among Aircraft Maintenance Engineers

Period of Work	Work Fatigue						Total		P-Value
	Very Tired		Tired		Less Tired				
	n	%	n	%	n	%	n	%	
Length of time	13	24,5	28	52,8	12	22,6	53	100	0,002
Medium	8	22,2	9	25	19	52,8	36	100	
New	1	5,9	4	23,5	12	70,6	17	100	
Total	22	20,8	41	38,7	43	40,6	106	300	

There was a significant association between work duration and fatigue (p = 0,002) with long-service workers showing the highest level of fatigue (52,8 %). These results suggest that long work duration increases the risk of fatigue due to routine and repetitive workload.

Table 4. Influence between Smoking Habits and Occupational Fatigue in Aircraft Maintenance Engineers

Smoking Habit	Work Fatigue						Total		P-Value
	Very Tired		Tired		Less Tired				
	n	%	N	%	n	%	n	%	
Weight	18	41,9	15	34,9	10	23,3	43	100	0,000
Medium	2	8	12	48	11	44	25	100	
Lightweight	1	7,7	2	15,4	10	76,9	13	100	
No Smoking	1	4	12	48	12	48	25	100	
Total	22	20,8	41	38,7	43	40,6	106	300	

A significant association was found between smoking and work fatigue (p = 0,000) with heavy smokers experiencing higher fatigue (41,9 %) than non-smokers (4 %). This suggests that smoking worsens physical conditions and reduces work capacity.

Table 5. Influence between Sleep Quality and Work Fatigue in Aircraft Maintenance Engineers

Sleep Quality	Work Fatigue						Total		P-Value
	Very Tired		Tired		Less Tired				
	n	%	N	%	n	%	n	%	
Bad	21	23,9	38	43,2	29	33	88	100	0,002
Good	1	5,6	3	16,7	14	77,8	18	100	
Total	22	20,8	41	38,7	43	40,6	106	200	

There was a significant association between sleep quality and fatigue (p = 0,002) with 43,2 % of respondents who had poor sleep quality experiencing fatigue. Workers with good sleep quality tend to have lower levels of fatigue, emphasizing the importance of adequate rest to maintain work performance.

Table 6. Influence between Marital Status and Occupational Fatigue in Aircraft Maintenance Engineers

Marital Status	Work Fatigue						Total		P-Value
	Very Tired		Tired		Less Tired				
	n	%	N	%	n	%	n	%	
Married	21	26,9	36	46,2	21	26,9	78	100	0,000
Not Married	1	3,6	5	17,9	22	78,6	28	100	
Total	22	20,8	41	38,7	43	40,6	106	200	

Marital status had a significant effect on fatigue (p = 0,000) with married workers experiencing more fatigue (46,2 %) than unmarried workers (17,9 %). This indicates that family responsibilities can add to workers' psychological and physical stress.

Table 7. Influence between Physical Workload and Occupational Fatigue in Aircraft Maintenance Engineers

Physical Workload	Work Fatigue						Total		P-Value
	Very Tired		Tired		Less Tired				
	n	%	N	%	n	%	n	%	
Weight	14	27,5	29	56,9	8	15,7	51	100	0,000
Lightweight	8	14,5	12	21,8	35	63,6	55	100	
Total	22	20,8	41	38,7	43	40,6	106	200	

Results showed a significant association between physical workload and fatigue (p = 0,000) where workers with heavy physical loads experienced higher fatigue (56,9 %) than those with light loads (21,8 %). This illustrates that high physical activity directly contributes to increased fatigue.

Table 8. Influence between Mental Workload and Occupational Fatigue in Aircraft Maintenance Engineers

Mental Workload	Work Fatigue								
	Very Tired		Tired		Less Tired		Total		P-Value
	n	%	N	%	n	%	n	%	
High	7	25	14	50	7	25	28	100	0,008
Medium	11	24,4	20	44,4	14	31,1	45	100	
Lightweight	4	12,1	7	21,2	22	66,7	33	100	
Total	22	20,8	41	38,7	43	40,6	106	300	

Table 9. Model fitting information results

	-2 Log Likelihood	Chi-Square	Df	Sig
Intercept Only	210,358			
Final	152,795	57,563	8	0,000

There was a significant association between mental workload and fatigue (p = 0,008), with workers with high mental workload experiencing greater fatigue (50 %) than those with low mental workload (21,2 %). This suggests that cognitive stress and job demands influence the level of fatigue of aircraft technicians.

The Chi-Square value of 57,563 with p = 0,000 indicates that the logistic regression model used is feasible and statistically significant. This means that the independent variables are able to explain variations in job fatigue significantly.

Table 10. Goodness-of-Fit Test Results

	Chi-Square	df	Sig
Pearson	163,244	158	0,371
Deviance	140,966	158	0,831

The Goodness-of-Fit values show Pearson's p-value = 0,371 and Deviance = 0,831 both greater than 0,05, which means the model has a good fit with the observed data. This model can accurately represent the relationship between variables.

Table 11. Results of the Proportional Odds Assumption Test (Test of Parallel Lines)

Model	2 Log Likelihood	Chi-Square	Df	Sig
Null Hypothesis	152,795			
General	139,106	13,689	8	0,90

The Test of Parallel Lines test result with p = 0,90 (>0,05) indicates that the proportional odds assumption is met. This means that the ordinal logistic regression model used is appropriate and can be interpreted validly.

Table 12. Model Strength Test Results (Pseudo R-Square)

Cox and Snell	0,419
Nagelkerke	0,476
McFadden	0,256

The Pseudo R-Square value shows a fairly strong model contribution with Cox & Snell = 0,419 Nagelkerke = 0,476 and McFadden = 0,256, which means that the independent variables are able to explain about 47,6 % of the variation in work fatigue in aircraft technicians.

Table 13. Test Results of Effect and Direction of Effect (Parameter Estimates)

		Estimate	Std.Error	Wald	df	Sig
Thereshold	Fatigue 1	3,641	1,078	11,413	1	0,001
	Fatigue 2	6,317	1,222	26,705	1	0,000
Location	Age	-1,136	0,544	4,360	1	0,037
	Period of Employment	0,555	0,374	2,196	1	0,138
	Marital Status	2,227	0,685	10,565	1	0,001
	Mental Workload	-0,260	0,335	0,602	1	0,438
	Physical Workload	1,4909	0,496	8,069	1	0,005
	Sleep Quality	1,212	0,712	2,899	1	0,089
	Smoking Habit	0,689	0,19	13,184	1	0,000

The test results show that the variables of age (p = 0,037) marital status (p = 0,001) physical workload (p = 0,005) and smoking habit (p = 0,000) have a significant effect on job fatigue. While tenure, mental workload, and sleep quality had no significant effect. This means that physical factors, lifestyle and social conditions are more dominant in influencing the level of fatigue in Aircraft Maintenance Engineers.

DISCUSSION

Effect of Age on Work Fatigue

This study found a significant relationship between age and work fatigue among Aircraft Maintenance Engineers (AMEs) at Sultan Hasanuddin International Airport Makassar in 2025. Physiologically, aging results in decreased cardiovascular efficiency, muscle strength, oxygen uptake, and slower cellular recovery, which collectively contribute to fatigue accumulation. However, older workers often compensate for declining physical capacity through experience, task familiarity, and adaptive work strategies. These results align with study [11] which demonstrated that older workers in the motor parts industry exhibited higher fatigue levels ($p = 0,041$; $r = 0,396$). Likewise, Rombedatu et al.[12] noted that aging employees showed slower recovery rates and more frequent subjective fatigue complaints, particularly in labor-intensive environments. However, Ismah et al.[13] emphasized that strong work engagement mitigates fatigue and enhances job satisfaction, suggesting that psychological resilience and engagement can moderate the physiological effects of aging. The combination of physical decline and psychosocial adaptation creates a complex relationship—older AMEs may experience physical tiredness but not necessarily mental exhaustion if supported by good work design and engagement. Hence, organizational implications include implementing age-sensitive workload distribution, ergonomic support, and continuous training to optimize performance among older technicians while preventing overfatigue.

Relationship between Working Period and Work Fatigue

The study also identified a significant relationship between tenure and work fatigue. Longer tenure is commonly associated with greater task repetition, reduced novelty, and monotony, which may lead to psychological fatigue. Conversely, extended experience can enhance efficiency and reduce mental strain through skill mastery. This bidirectional effect reflects the complexity of tenure as both a risk and a protective factor. Research[14] found similar results among garbage workers, where longer tenure correlated with higher fatigue due to monotonous workloads and repetitive exposure. However, Khairunnysa and Balqis[15] discovered that tenure's effect on performance is mediated by job satisfaction—workers who perceive meaning and stability in their roles tend to exhibit lower fatigue despite long service. These findings imply that tenure-related fatigue may be minimized through organizational interventions such as job rotation, motivational programs, and recognition systems. For AMEs, repetitive maintenance tasks can be balanced with skill diversification and technical mentorship programs to sustain enthusiasm and reduce cumulative fatigue risk.

Effect of Smoking Habit on Work Fatigue

Smoking habits demonstrated a strong relationship with work fatigue. Biologically, smoking leads to decreased oxygen transport due to carbon monoxide binding to hemoglobin, impaired pulmonary function, and vascular constriction—all contributing to decreased physical endurance and faster onset of fatigue. Additionally, nicotine disrupts sleep cycles and induces physiological stress that exacerbates daytime fatigue. Supporting evidence from research [16] found that heavy smokers reported significantly higher fatigue levels ($p = 0,026$). Mugniyah et al.[17] similarly emphasized that non-physical factors such as smoking, stress, and poor air quality intensify occupational fatigue. Within high-safety environments like aviation maintenance, smoking not only affects personal stamina but may also indirectly compromise concentration and accuracy during critical maintenance tasks. The implication is clear organizations should promote smoke-free policies, provide cessation programs, and integrate health education emphasizing the link between respiratory health and occupational safety. Given that fatigue in aviation can lead to operational hazards, smoking control becomes a critical aspect of fatigue management.

Effect of sleep quality on work fatigue

The analysis revealed a significant association between sleep quality and work fatigue. Sleep serves as the body's primary recovery mechanism, facilitating cognitive restoration, hormonal balance, and muscular repair. Poor sleep quality disrupts the circadian rhythm, leading to decreased alertness, impaired decision-making, and cumulative exhaustion—factors critical in aviation maintenance operations where precision is paramount. Study [18] found similar results among dump truck drivers, demonstrating that poor sleep increased fatigue and accident risk. However [19] showed inconsistent outcomes in rotating-shift security guards, where adaptation mechanisms mitigated fatigue. This inconsistency reflects the influence of individual coping abilities and work system design. Ismah et al.[13] also found that high work engagement improved job satisfaction and reduced fatigue even under suboptimal rest conditions. The implication is that sleep management programs—such as controlled shift scheduling, rest optimization, and education about sleep hygiene—should be institutionalized. In the aviation industry, promoting rest discipline is essential to ensure both worker health and flight safety.

Effect of physical workload on fatigue

Physical workload exhibited the most significant correlation with fatigue. AMEs are exposed to repetitive

lifting, crouching, and handling of heavy mechanical parts under time pressure and environmental stress (e.g., noise, heat, vibration). Continuous muscular activity without sufficient recovery results in lactic acid buildup and metabolic fatigue, directly impacting endurance and alertness. Study [20] in wood furniture manufacturing revealed a similar pattern, confirming the universality of this relationship across industries. Ramadhan et al.[21] also found that physical workload and heat exposure increased fatigue among bus drivers in Makassar, suggesting that ergonomic stressors are key determinants of fatigue regardless of occupation. This evidence underscores the need for ergonomic redesign—such as mechanical aids, work-rest cycles, and physical conditioning—to minimize musculoskeletal strain. As emphasized by Rombedatu et al.[12], neglecting ergonomic adaptation leads to cumulative fatigue, which may escalate into chronic health conditions. Therefore, managing physical workload is both a productivity and safety imperative.

Effect of mental workload on job burnout

Mental workload showed a significant association with fatigue levels. The tasks performed by AMEs—diagnostic reasoning, fault analysis, and technical decision-making—require sustained cognitive effort. Excessive mental workload without adequate recovery results in cognitive overload, decreased focus, and emotional exhaustion. Research [22] indicated that mental workload contributes indirectly to fatigue through its impact on sleep quality. This aligns with Mugniyah et al.[17], who found that a poor non-physical environment, characterized by time pressure and limited cognitive breaks, increases fatigue and stress. However, mental workload can be mitigated through structured procedures, teamwork, and training, enabling AMEs to manage cognitive demands effectively. The implication is that organizations should integrate mental workload monitoring systems, provide mindfulness or resilience training, and ensure adequate rest intervals between complex maintenance tasks to maintain mental clarity and prevent cognitive fatigue.

Effect of marital status on job burnout

Marital status was significantly associated with fatigue, where married workers experienced higher fatigue levels than unmarried ones. This is attributed to the dual burden of occupational and family responsibilities, leading to reduced rest, increased psychological tension, and fragmented recovery time. Previous studies confirmed this association, noting that married health workers and employees at community health centers in Malang experienced higher burnout levels due to role conflict.[23,24] Khairunnysa and Balqis[15] also reported that psychosocial pressures from domestic roles influence overall performance and fatigue. In contrast, Ismah et al.[13] argued that strong work engagement and social support could buffer the negative impact of marital demands. These findings suggest that fatigue is not purely a physiological phenomenon but also a psychosocial one. The organization can mitigate this through family-friendly policies, flexible schedules, and psychosocial support systems to help employees balance work and personal life demands.

Taken together, the study confirms that work fatigue among Aircraft Maintenance Engineers (AMEs) results from a complex interaction of demographic, behavioral, and occupational factors. Variables such as age, marital status, smoking habits, sleep quality, workload, and tenure collectively shape the levels of fatigue experienced by workers. These findings align with the holistic ergonomics model, which perceives fatigue as a multidimensional construct encompassing physical, cognitive, and psychosocial dimensions. Within this framework, fatigue is not simply the result of physical exhaustion but also of mental and emotional strain influenced by lifestyle and organizational conditions. The combination of physiological decline, behavioral habits, and psychosocial stress underscores that fatigue management must address workers as whole individuals rather than focusing on isolated aspects of their labor.

In practical terms, the findings highlight the urgent need for integrated fatigue risk management systems in the aviation maintenance sector. Such systems should incorporate regular health surveillance, workload monitoring, and psychological support to identify and address early signs of fatigue. Interventions such as smoking cessation programs, sleep quality improvement initiatives, and stress management workshops can also play critical roles in promoting worker resilience and performance sustainability. Organizational policies must encourage balanced shift scheduling, ergonomic task design, and recovery opportunities to maintain worker alertness and prevent operational errors. Effective fatigue management does not merely safeguard individual well-being but also enhances overall maintenance quality, reduces safety risks, and improves reliability in aviation operations.

This study, however, acknowledges several limitations that shape the interpretation of its findings. Its cross-sectional design limits the ability to infer causality between identified variables and fatigue, while reliance on self-reported questionnaires introduces potential recall and response bias. Environmental factors such as temperature, humidity, noise, and lighting were not measured quantitatively, and psychological dimensions like motivation, stress, and work engagement were not directly analyzed, despite their importance. The focus on a single airport setting also restricts the generalizability of results to broader aviation contexts. Future research should adopt longitudinal and mixed-method approaches that combine physiological measurements—such as

cortisol levels and actigraphy—with qualitative exploration of workplace culture and management practices. Despite these limitations, the study provides meaningful empirical insight into the multidimensional nature of fatigue among AMEs and offers practical guidance for improving occupational health, safety, and operational excellence in high-stakes maintenance environments.

CONCLUSIONS

Based on the results of research on the Analysis of Determinants of Work Fatigue in Aircraft Maintenance Engineers at Sultan Hasanuddin International Airport Makassar in 2025, it can be concluded that age, smoking habits, physical workload, and marital status have a significant effect on work fatigue, while tenure, sleep quality, and mental workload have no effect multivariately although they show a bivariate relationship. Young workers and heavy smokers tend to experience fatigue more easily, while married workers face additional pressure from family responsibilities. The higher the physical workload, the greater the risk of fatigue experienced by technicians. Therefore, prevention efforts need to focus on managing physical workload, improving sleep quality, reducing smoking, and supporting work and family balance. For companies, it is important to implement workload management systems, health education programs, and periodic monitoring of technicians' conditions, while future researchers are advised to expand the research variables and involve more specific psychosocial or work environment factors.

REFERENCES

1. Sarbiah A. Penerapan Pelaksanaan Keselamatan dan Kesehatan Kerja (K3) pada Karyawan. Cura al Inf J Penelit. 2023;15(2):e1210-e1210.

2. Ananda DE, Mustopa. Hubungan Shift Kerja, Lingkungan Fisik Kerja Dan Beban Kerja Dengan Kelelahan Kerja Karyawan Bagian Produksi Di Pt. Medifarma Tahun 2022. J Kesehat dan Kedokt. 2023;2(1):76-82.

3. Sitanggang R, Nabela D, Putra O, Iqbal M. Pengaruh Usia, Masa Kerja Dan Shift Kerja Terhadap Kelelahan Kerja Pada Operador Alat Berat Di. J Kesehat Tambusai. 2024;5:3168-75.

4. Dewi L, Studi P, Masyarakat K, Abdi S. Faktor Yang Berhubungan Dengan Kelelahan Kerja Pada Pekerja Bagian Wet Procees (Proses Basah). 2024;16(1):198-208.

5. Wijanarti HL. Hubungan Antara Kualitas Tidur, Beban Kerja Fisik Terhadap Perasaan Kelelahan Kerja Pada Perawat Rawat Inap Kelas 3 Di Rs Pku Muhammadiyah Gamping. J Lentera Kesehat Masy. 2022;33(1):1-12.

6. Maudy CK, Ruliati LP, Doke S. Keluhan Musculoskeletal Disorders y Kelelahan Kerja pada Tenaga Kerja Bongkar Muat di Pelabuhan Tenau. Medios Kesehat Masy. 2021;3(3):312-21.

7. Besse NA. Control de Movimiento de Plataforma de la Unidad Peran (Amc) Dalam Menjamin Keselamatan Penerbangan Di Bandar Udara Internasional Sultan Hasanuddin Makassar. J Publ Ekon y Akunt. 2022;2(3):307-17.

8. Silva JC da, Barqueira A, Magalhães LB, Santos LFFM. Fatiga humana en el entorno de mantenimiento de aeronaves. Ciencia segura. 2024;180(106634).

9. Trissiana F. Hubungan Antara Tiempo Presión Dengan Acción insegura Saat Transit Check Pada Teknisi Pesawat Terbang. Indones J Occup Saf Heal. 2018;7(2):210.

10. Ristantya AR, Kurniawan B, Wahyuni I. Hubungan Antara Karakteristik Pekerja Dan Pengawasan Terhadap Perilaku Tidak Aman Pada Teknisi Perawatan Hangar Pesawat Pt X. J Kesehat Masy. 2022;10(3):267-72.

11. Jihan Ufairah Hasna. Relación entre la edad y la antigüedad laboral con la fatiga laboral en trabajadores de la industria de repuestos para motocicletas. World J Adv Res Rev. 2023;18(3):1036-40.

12. Rombedatu AT, Saleh LM, Yusbud M. FAKTOR YANG BERHUBUNGAN DENGAN PERASAAN KELELAHAN KERJA PADA. Hasanuddin J Salud Pública. 2025;6(1):97-109.

13. Ismah A, Arifah N, Sari N. HUBUNGAN COMPROMISO LABORAL TERHADAP KEPUASAN KERJA PADA STAF DI RUMAH SAKIT STELLA MARIS. Hasanuddin J Salud Pública. 2024;5(1):24-32.

14. Pasenggong MWL, Sabilu Y, Nurmaladewi. Hubungan Beban Kerja, Lama Kerja, Dan Masa Kerja Dengan

Kelelahan Pada Pekerja Pengangkut Sampah Di Kota Kendari Tahun 2022 la relación entre la carga de trabajo, la duración del trabajo y el período de trabajo con fatiga entre los transportistas de residuos en la ciudad de Kendari 2022. J Kesehat dan Keselam Kerja Univ Halu Oleo. 2024;5(1):21-9.

15. Khairunnysa, Balqis. FAKTOR YANG BERPENGARUH TERHADAP KINERJA PEGAWAI DI PUSKESMAS KOTA PANGKAJENE KABUPATEN PANGKEP TAHUN 2025. Hasanuddin J Public Heal. 2025;6(2):220-9.

16. Dasril O, Aria R, Sary AN. Faktor-Faktor Yang Berhubungan Dengan Kelelahan Kerja Pada Pekerja Bagian Produksi Pt Kunango Jantan. Ensiklopedia J. 2024;7(1):264-72.

17. Mugniyah AA, Darwis AM, Wahyuni A. Relación entre el entorno laboral físico y no físico con el estrés laboral. Hasanuddin J Public Heal. 2023;4(2):159-70.

18. Anggara A, Haidir H. Kualitas Tidur dan Hubungannya dengan Kelelahan Kerja (Fatiga) pada Pengemudi Dump Truk di Pertambangan. Anterior J Kesehat Masy. 2024;15(3):1-11.

19. Sunarno SD, Ramdhan DH, Efendi H, Amalaili P, Rizky ZP. Estudio del trabajo por turnos, la cantidad y la calidad del sueño y la aparición de fatiga en la Universidad de Seguridad de Indonesia. KnE Life Sci. 2018;4(5):709.

20. Reppi GC, Suoth LF, Kandou GD. Hubungan antara Beban Kerja Fisik dengan Kelelahan Kerja pada Pekerja Industri Pembuatan Mebel Kayu di Desa Leilem Satu. Med Scope J. 2019;1(1):21-5.

21. Ramadhan R, Awaluddin, Darwis AM. FAKTOR-FAKTOR KELELAHAN KERJA PADA PRAMUDI BUS TRANS MAMMINASATA DI KOTA MAKASSAR. Hasanuddin J Salud Pública. 2025;6(1):33-45.

22. Kusmawan D, Izhar MD, Aswin B. Evaluación de la relación entre la carga mental y la fatiga laboral entre los trabajadores del sector de petróleo y gas en PT X, provincia de Jambi, Indonesia: análisis PLS-SEM. J Public health Res. 2024;13(4).

23. Ihsania E. Gambaran Kelelahan Kerja Pada Kurir Pengantar Barang Di Wilayah Tangerang Selatan Tahun 2020. UIN Syarif Jakarta; 2020.

24. Aisyah M, Supriyadi, Laksana DP, Marji. Kelelahan Kerja: Gambaran Beban Kerja Fisik, Kualitas Tidur, dan Status Pernikahan pada Tenaga Kesehatan. Curación de ciencia deportiva. 2025;7(1):1-14.

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