International Journal of Health Sciences

Available online at www.sciencescholar.us
Vol. 6 No. 3, December 2022, pages: 1556-1564
e-ISSN: 2550-696X, p-ISSN: 2550-6978
https://doi.org/10.53730/ijhs.v6n3.13248

Physical Environment and Work Fatigue Among Ship Engine Room Crew

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Manuscript submitted: 14 April 2022, Manuscript revised: 08 June 2022, Accepted for publication: 05 September 2022

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Keywords

engine room crew;
Manado port;
physical environment;
ship;
work fatigue;

Abstract

The physical environment of a ship is often found to be below the government's standard, which affects employees' health and causes work fatigue. The present study aimed to identify the physical environment and work fatigue in the ship engine room at Manado Port by applying a cross-sectional analytical approach. The study population was forty-one engine room crew of seven ships with Manado-Talaud Archipelago routes with 7-16 hours trip. The research instrument includes a hygrometer, sound level meter, vibration meter, and work fatigue questionnaire (KAUP2). The data were analyzed descriptively and by performing a correlation test. The study found that the ships' temperature, noise, and vibration exceeded the stipulated threshold limit value. The relationship between the physical environment and work fatigue was also noticed.

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1 Introduction

Indonesia is a maritime country whose territory is dominated by sea. North Sulawesi and its capital city, Manado, is a province consisting of 329 islands (Statistics Indonesia, 2021). In this regard, inter-island transportations are mostly done by ships. In order to optimize Indonesia's wide sea, sea transportation should be optimally supported by shipping industries (Rochwulaningsih et al., 2019; Zen, 2021). A number of aspects should be addressed to support this sector, including the technical aspects during the production process, engine maintenance, and standard maintenance. The latter particularly includes physical environment like vibration, noise, temperature, and lighting of each room (Parsons, 1995; Palella et al., 2016) Failure to address these aspects according to the standard may affect workers' fatigue and potentially causes accidents in the workplace (Akhtar & Utne, 2014). Work fatigue and workplace accident, physical environment is also associated with workers' stress (Wong et al., 2002) and digestive disorders.

Working in a ship is one of the high-risk jobs, particularly those in the engine room. Preliminary interviews with several engine room crews in Manado Port revealed their complaint of high noise, high room temperature and humidity that cause dizziness and fatigues. Previous studies report that work environment conditions may contribute to work fatigue, eventually causing health problems and work-related diseases (Meeusen et al., 2006; Yu et al., 2019; Lindgren et al., 2022).

Work fatigue is one of the common problems workers face, which could be categorized into two types: physical and mental fatigue. Mental fatigue is related to psychological aspects, while physical fatigue is related to muscle fatigue (Grandjean, 1979; Lal & Craig, 2001). Both types of fatigue may result in decreased attention, concentration, and motivation. Fatigue slows down one's cognitive process, and mental fatigue is commonly indicated by general fatigue sensations, increased reaction time, lower attention, and reticence in exercising any activity (Grandjean, 1979). Psychological stresses are mostly found in workers with a heavy workload, limited workspace, and poor environmental conditions (García-Herrero et al., 2012).

One's actual fatigue level, causes, and mechanism are still unclear considering that it is caused by multiple factors and results in complex effects. The fatigue prevalence is reported to range between 7 % and 45 % (Ricci et al., 2007; Zhan et al., 2020; Rachmawati et al., 2020). Previous studies also report a strong relationship between fatigue and risk of accident (Baldauf et al., 2002; Williamson et al., 2011).

Engine room crew is one of the high-risk jobs as they encounter various physical environment disruptions that may result in work accident, unless the occupational health and safety principles are properly implemented. This study examines the physical environments and work fatigue among engine room crews in Manado Port.

2 Materials and Methods

This cross-sectional analytical study Involved forty-one engine room crews in seven ships in Manado Port as research participants. This study also examined the physical environment of their ships' engine room. The ship samples used in this study were passenger ships. Hygrometer, sound level meter, and vibration meter were used to measure the temperature, noise, and vibration, respectively. These devices had been calibrated prior to use. A 17-item work fatigue questionnaire (KAUPK2) with likert scale was deployed to measure crews' fatigue subjectively. The physical environment measurement was performed during the ship's round trip in order to obtain the mean value of each parameter, while work fatigue was measured when the crews finished their works. The physical environment measurement was compared to the Threshold Limit Value stipulated in Indonesia, while the work fatigue was scored and categorized into three groups: less exhausted,

exhausted, and very exhausted. This study has received ethical approval from Manado Ministry of Health's Health Polytechnic. All respondents in this study have also given their consent to participate by signing an informed consent form. The data were analyzed descriptively and by performing correlation test.

3 Results and Discussions

Table 1
Respondent's characteristics

Category	n	%
Age		
< 25 years	10	24.4
26 – 35 years	20	48.8
>36 years old	11	26.8
Length of Service		
>5 years	7	17.1
≤ 5 years	34	82.9
Work Fatigue		
Exhausted	35	85.37
Very Exhausted	6	14.63

As displayed in Table 1, most respondents were relatively young, averaging 31 years of age. This implies that working as a ship crew requires more physical strength to handle high physical demands and heavy workloads (Österman et al., 2020). This job is also often done at night and takes more than eight hours.

Regarding working experience, 82.9% of participants reported having more than 5 years of experience. This aspect is crucial for ship engine crew, considering its high risks. Moreover, they are also demanded to be able to solve engine problems anytime during the trip. 85.37% of crews involved this study were categorized as exhausted, while the rest, 14.63%, were categorized as very exhausted. This finding is consistent with (Kusuma & Susilowati, 2020), reporting that 79.28% cruise ship workers were categorized as exhausted, while 8.11% of them were categorized as very exhausted.

Table 2
Ship engine room physical environment

Ship	Physical environment		
	Temperature (mean)	Noise (mean)	Vibration (mean)
Ship B	37.35^{0}C	101.85 dB	1.87 m/second
Ship HM	35.95^{0}C	101.30 dB	1.32 m/second
Ship ST	34.67^{0}C	95.32dB	2.07 m/second
Ship V	31.85^{0}C	96.75 dB	2.10 m/second
Ship MT	36.72^{0}C	98.92 dB	1.17 m/second
Ship MRT	34.27^{0}C	95.27 dB	1.32 m/second
Ship MB	32.92^{0}C	100.20 dB	1.07 m/second

As presented in Table 2, the lowest average temperature was 31.85^{0}C, while the highest was 37.35^{0}C. Compared to the prevailing regulation, this average temperature had exceeded the threshold value, i.e., 18^0-30^{0}C (Kepmenkes RI No. 1405, 2002). This high temperature appears to be accounted for by the ship's long route (up to 16 hours), which causes the engine to work longer, in addition to the engine room's lacked

ventilation. Workers exposed to heat are prone to injury, diseases, poor productivity, and even death. Workers exposed to extreme heat while working on heavy physical activity are prone to work-related diseases due to heat stress, including heat stroke, exhaustion, heat cramps, and even death. Heat also increases the risk of injured workers, as it causes sweaty hand palms, foggy safety glasses, dizziness, and reduces one's reasoning ability in decision-making processes (Jacklitsch et al., 2016).

The noise intensity was also found to range between 92.32 dB and 101.85 dB, far exceeding the threshold value of 85 dB (Kepmenaker, 2018). Ships with lower noise intensity usually have installed noise insulation in their engine room, while those with higher noise intensity have not. The survey result showed that almost all workers wear personal protective equipments when working in the ship engine room. Short-term exposure to high noise can cause temporary hearing disorder, and continuous exposure to high noise can cause uncorrectable, permanent hearing disorders (Tolmacheva et al., 2021). Loud noise can also induce physical and psychological stress, lower productivity, distract communication and concentration, and contribute to accidents and injuries in the workplace as it prevents worker from hearing alarms. noise-induced hearing disorders may cause considerable problems, prevent individuals from listening to high-frequency sound and understanding speech, and significantly hinders communication skills (European Agency for Safety and Health at Work, 2005).

The vibration value was found to range from 1.07m/s to 2.10 m/s, which was also beyond the Threshold Limit Value of 0.40 m/s ^{2}(Kepmenaker, 2018). The survey and interviews with ship engine crews showed that ships with low vibration intensity were usually those that had installed a new engine, while those with high vibration were those lacking regular maintenance (e.g., oil change) and poor engine mounting.

Workers in ship and fishery industries are usually exposed to whole body vibration and hand-arm vibration produced by the engine, lifting equipment, or ship movement, particularly in a rough water (Krajnak, 2018). Continuous, prolonged exposures to hand-arm and whole-body vibrations are reported to increase the risk of Musculoskeletal Disorders (MSD), peripheral vascular and sensorineural issues, decreased touch sensitivity, loss of manual dexterity, and vasospasm (Bovenzi, 2010; Krajnak, 2018).

Table 3
Physical environment factors-work fatigue relationships

Variable	r	*p - Value*
Temperature- Work Fatigue	0384	0026
Noise-Work Fatigue	0238	0047
Vibration- Work Fatigue	0915	0023

The analysis result indicates a significant relationship between temperature and work fatigue, as indicated by an r value of 0.256 with a p-value of 0.026. The result implies that higher temperature causes workers to be exhausted faster. This study support previous studies stating that temperature in the workplace may affect fatigue (Tanabe et al., 2007; Micone & De Waele, 2017). Previous study has reported a difference between workers working below threshold values and above threshold values (Ramdan, 2007).

The analysis result also found a significant relationship between noise and work fatigue, as indicated by an r value of 0.238 with a *p-value* of 0,047. This implies that higher noise may result in faster exhaustion. This finding is consistent with previous studies reporting that noise affects workers' fatigue (Lai & Huang, 2019; Watulinggas et al., 2020; Syuhada & Widodo, 2020). Lastly, analysis result found that vibration is significantly related to work fatigue, as indicated by (r =0.915 p = 0.023), meaning that higher vibration causes workers to be exhausted faster. In addition work fatigue, vibration also causes work stress (Hendrawan & Nusantara, 2019), sleep disorder, increased temperature and blood pressure (Picu et al., 2019).

4 Conclusion

Physical environment is one of the factors affecting workers' fatigue. Therefore, it is recommended to enforce occupational health and safety regulations consistently by controlling, maintaining, and monitoring the ship's engine regularly, enforcing 8 working hour limitation, and use of personal protective equipments.

Acknowledgments
We would like to thank the Head of Manado Port Health Office and all participants for their participation in this study.

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