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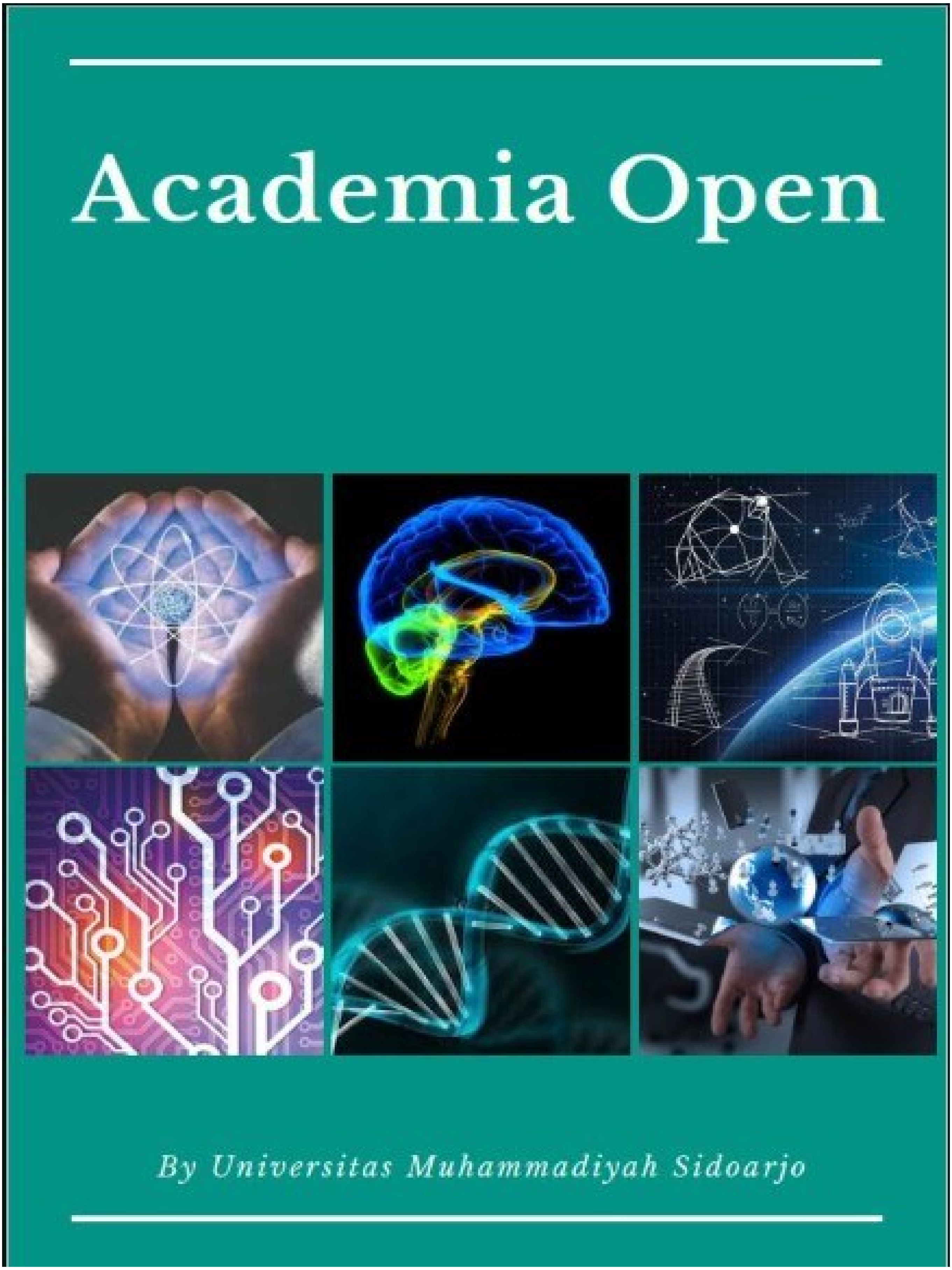

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High Postural Risk in Air Fin Cooler Maintenance Operators

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Abstract

General Background: Ergonomic work posture assessment is essential for reducing musculoskeletal disorder risk and supporting occupational safety in industrial maintenance activities. **Specific Background:** PT XYZ, a petrochemical company in the Gresik Industrial Area, operates 94 Air Fin Cooler units maintained by 38 operators who work for 2 to 16 hours at approximately 2 meters height in non-ergonomic postures. **Knowledge Gap:** A comprehensive assessment combining Ovako Working Posture Analysis System and Loading on the Entire Body Assessment had not been fully applied to Air Fin Cooler maintenance operators. **Aims:** This study aimed to assess working posture risk among Air Fin Cooler maintenance operators using OWAS and LEBA and to provide ergonomic improvement recommendations. **Results:** OWAS assessment showed that 19 operators, or 50%, were at action level 1; 11 operators, or 28.9%, were at action level 2; and 8 operators, or 21.1%, were at action level 3, with OWAS code 2362 identified as the most hazardous posture. LEBA results showed no operators in the low-risk category, with a mean total score of 14.6 in the high category. In total, 22 operators, or 57.9%, were in the high category, while 6 operators, or 15.8%, were in the very high category. **Novelty:** This study combines OWAS and LEBA to evaluate whole-body postural load in petro chemical maintenance work. **Implications:** Recommended actions include an Industrial Folding Ladder, improved scaffolding design, and active rest for 10–15 minutes every 45–60 minutes.

Highlights:

-
- OWAS code 2362 was identified as the most hazardous posture.
- No operator was classified in the low-risk LEBA category.
  Active rest and safer access equipment were recommended.

Keywords: Air Fin Cooler, Ergonomics, LEBA, Musculoskeletal Disorders, OWAS

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Introduction

PT XYZ is a petrochemical company established on May 9, 1996, that commenced commercial operations in 1998. Located in the Gresik Industrial Estate, East Java, the company is a subsidiary of the Pertamina Group. The plant is a major producer of intermediate chemicals in Indonesia and Southeast Asia, primarily manufacturing 2-Ethyl Hexanol (2-EH), Iso-Butanol (IBA), Normal Butanol (NBA), and liquid CO_2 materials used as feedstocks for the plastics, solvent, paint, resin, and chemical additive industries. Additionally, the company processes waste gas into liquid carbon dioxide (LCO_2) for industrial reuse. The plant employs various industrial support systems such as reactors, condensers, heat exchangers, and cooling systems to maintain the thermal stability of chemical reaction processes during production [1].

A critical component of this cooling infrastructure is the air fin cooler, a heat exchanger that utilizes air as the primary cooling medium. Air-fin coolers consist of metal pipes equipped with fins to increase the heat transfer surface area, allowing heat from the fluid inside the pipes to be efficiently dissipated into the surrounding air. These units are widely used in the petrochemical industry because they can lower the temperature of reaction fluids or gases prior to condensation without requiring large quantities of cooling water. At PT XYZ, the use of air-fin coolers plays a vital role in maintaining process temperature stability, mitigating the risk of overheating, and enhancing energy efficiency. Furthermore, this air based cooling system helps the company conserve water and reduce the operational and maintenance costs typically associated with water based cooling systems. Consequently, air fin coolers play a strategic role in supporting smooth petrochemical production at PT XYZ, preserving equipment performance, and ensuring that chemical product quality remains consistent and compliant with industry standards [2]. If the air fin cooler malfunctions, the cooling system's performance declines, preventing optimal control of process temperatures. This situation can lead to increased operating pressures and temperatures, accelerate component wear, reduce production efficiency, and heighten the risk of operational disruptions or even unplanned shutdowns, resulting in time and financial losses for the company.

Air fin cooler maintenance is divided into heavy and light maintenance. Heavy maintenance, such as bearing and motor replacement, typically takes 12–16 hours and requires a machine shutdown, while light maintenance, such as bearing lubrication or V-belt replacement, takes around 2–4 hours. These activities involve 3–5 workers out of a total of 38, making working posture an important factor for ensuring smooth operations and safety [3]. Maintenance operators play a crucial role in maintaining equipment reliability, process continuity, and workplace safety. They are required to have technical skills for performing inspections, light to heavy maintenance, and to follow proper procedures and teamwork. However, maintenance tasks often involve non-ergonomic postures such as repetitive movements, working in confined spaces, lifting heavy components, and prolonged upward-looking positions. These conditions increase the risk of musculoskeletal disorders, especially since the work is performed at a height of approximately 2 meters over extended durations [4].

An initial survey using the Nordic Body Map was conducted on 38 maintenance workers aged 26 to 40 and ranging in height from 165 cm to 178 cm revealing musculoskeletal complaints across various body parts: 595 instances of no pain, 304 of mild discomfort, 142 of pain, and 23 of severe pain. The most prevalent complaints were localized in the neck, shoulders, upper and lower back, arms, and wrists, indicating physical workload and non-ergonomic postures during work tasks [5]. If these work-related complaints and ailments are not addressed promptly, operators risk a gradual decline in physical function, chronic musculoskeletal pain, spinal injuries, impaired muscle and joint function, and nerve disorders in the neck and arms all of which can compromise physical resilience and work concentration. In the long term, these conditions may lead to reduced work capacity, increased absenteeism, and for some workers an inability to perform optimally or even a permanent inability to work [6].

The following graph illustrates the impact on the company from January to December 2024 with incident totals of 8 in January, 10 in February, 8 in March, 9 in April, 7 in May, 9 in June, 6 in July, 6 in August, 6 in September, 9 in October, 8 in November, and 9 in December [7]. These impacts include an increase in workplace accidents and occupational illnesses, rising medical and compensation costs, increased operational downtime due to a shortage of healthy personnel, and a decline in productivity and the quality of maintenance outcomes. Furthermore, there is a potential disruption to operational continuity and the achievement of production targets, resulting in reduced machine performance during the process [8].

Identifying and minimizing the risk of injury resulting from non-ergonomic work postures requires an appropriate and comprehensive analysis method. The Ovako Working Posture Analysis System (OWAS) and Loading on the Entire Body Assessment (LEBA) are observational ergonomic methods used to assess work postures based on the mechanical loads exerted on the worker's body [9]. OWAS classifies work postures based on the positioning of the back, arms, and legs, as well as the workload, to determine the level of ergonomic risk; meanwhile, LEBA evaluates whole-body postural load by considering postural angles, external loads, and work duration (Kee, 2022). Consequently, combining these methods is suitable for analyzing the work postures of air fin cooler maintenance operators and serves as a basis for recommending ergonomic improvements [10]. This study proposes a novel approach by combining the OWAS and LEBA methods to evaluate postural risks during air fin cooler maintenance activities, thereby yielding a more comprehensive ergonomic analysis than the use of either method alone. The researchers anticipate that the study's findings will serve as a basis for designing improvements to operator work postures—through the application of ergonomic principles ultimately reducing the risk of musculoskeletal disorders and enhancing workplace safety [11].

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Method

A. Research Location and Time

This research was conducted at PT XYZ, a petrochemical production company located at Jl. Gubernur Suryo No. 134, Lumpur, Tlogopojok, Gresik District, East Java, focusing on the air fin cooler unit. The study was carried out from August 2025 to May 2026, ensuring sufficient data was gathered for analysis.

B. Problem Solving Process

The problem-solving process and research stages of this study are illustrated in the flowchart presented in Figure 1.

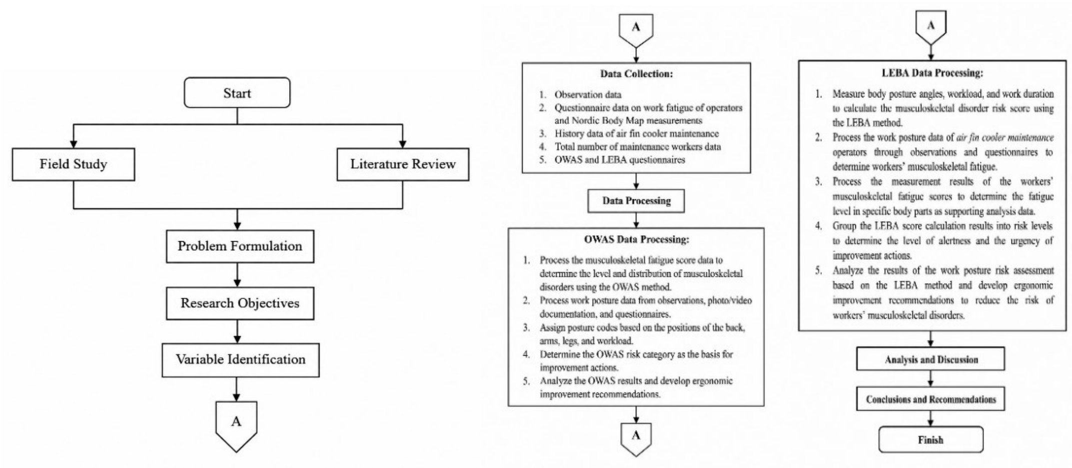

Figure 1. Problem-solving steps

The steps taken to address the problem in this study can be described as follows:

1. Start

This stage describes the initial steps before conducting the research, beginning with identifying the research problem at PT XYZ. After determining the research topic, research activities and observations are carried out.

2. Field Study

A field survey is conducted at the initial stage of the research to gain a deeper understanding of the actual conditions at PT XYZ through direct observation of problems occurring in the plant area. Therefore, the research implementation can be conducted more systematically, effectively, and in accordance with the established research objectives.

3. Literature Review

A leterature review was conducted to gather information regarding the Ovako Working Posture Analysis System (OWAS) and Loading on the Entire Body Assessment (LEBA) methods, drawing from relevant books, journals, and previous studies. The information obtained serves as a theoretical foundation and support the data collection, processing, and analysis stages of this research.

4. Problem Formulation

After identifying conditions at PT XYZ, the research problem is formulated to focus the study. This research analyzes air fin cooler maintenance operators' working posture using OWAS and LEBA methods and provides improvement recommendations to ensure clear and focused research objectives.

5. Research Objectives

The objectives of this study are to analyze the working posture of air fin cooler maintenance operators using the OWAS and LEBA methods and to provide recommendations for posture improvement. The findings are expected to contribute to enhancing ergonomics and occupational health and safety at PT XYZ.

6. Variable Identification

The identification of research variables is necessary to determine the variables examined in the study. In this research, the independent variable (X) is working posture, which is assumed to be a factor contributing to occupational accident risks. Meanwhile, the dependent variable (Y) is the performance of air fin cooler maintenance operators.

7. Data Collection

The researcher collects the data and information required to solve the identified problems. Data collection involves obtaining both primary and secondary data for the purpose of the research. The required data include:

a. Observation data

b. Operator complaint questionnaire data and Nordic Body Map assessment results

c. Air fin cooler maintenance history data

d. Number of maintenance workers

e. OWAS and LEBA assessment data

8. Data Processing Using the Ovako Working Posture Analysis System (OWAS) Method

Data processing in this study is carried out using the Ovako Working Posture Analysis System (OWAS) method to assess the working posture risks of air fin cooler maintenance operators. The data are obtained through direct observation, work activity documentation, and workers' musculoskeletal complaint questionnaires. The collected data are then analyzed by classifying working postures based on OWAS scores to determine the level of ergonomic risk.

9. Data Processing Using the Loading on the Entire Body Assessment (LEBA) Method

Data processing in this study is conducted using the Loading on the Entire Body Assessment (LEBA) method to evaluate the working posture risks of air fin cooler maintenance operators. Data were obtained through direct observation, documentation of work activities, and questionnaires regarding musculoskeletal complaints. Subsequently, the data were analyzed by classifying work postures based on LEBA scores, which served as the basis for evaluating working conditions and systematically formulating recommendations for posture improvement.

10. Analysis and Discussion

The collected data are analyzed to identify risks related to operators' working postures during maintenance. The results are used to provide improvement recommendations to reduce workplace accidents and enhance ergonomic risk management and occupational health and safety at PT XYZ.

11. Conclusions and Recommendations

This stage provides a summary of the research findings that address the formulated research problems, as well as recommendations proposed to the company based on the study results. The recommendations are expected to serve as a basis for decision-making in organizational development and as a reference for future research.

12. End

The final stage of the research is marked by the preparation of the final report in a systematic manner. The research results are expected to make a meaningful contribution to the company.

C. Data Collection Sources

Data collection begins with gathering information related to the research questions. It is used to obtain the required data to achieve research objectives. Data collection involves obtaining both primary and secondary data through various methods. These methods are generally classified into several approaches.

- Primary Data

This refers to data collected directly by the researcher through on-site visits to the location or company, using the following methods:
a. Observational data
b. Data from operator complaint questionnaires and Nordic Body Map measurements

- Secondary Data

Secondary data consists of data that has already been processed and collected from institutions or companies relevant to the research, namely:
a. Air fin cooler maintenance history data
b. Data on the number of maintenance personnel

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Result and Discussion

A. Data Collection

Data processing in this study uses the Ovako Working Posture Analysis System (OWAS) and Loading on the Entire Body Assessment (LEBA) methods. Both methods are applied complementarily to provide a more comprehensive assessment of ergonomic risks in air fin cooler maintenance operators at PT XYZ.

B. Data Processing

The second stage of product development is concept development, where target market needs are identified, alternative product concepts are created and analyzed, and one or more concepts are selected for further development and testing [12].

➢ Data Processing Using the OWAS Method

- Musculoskeletal Complaint Score of Air Fin Cooler Maintenance Operators

Data processing began by analyzing musculoskeletal complaints of air fin cooler maintenance operators using the Nordic Body Map, distributed to 38 workers. The results showed the highest complaints in the upper and lower neck (100%), followed by the shoulders, upper arms, and lower back. These findings indicate high-risk body areas caused by non-ergonomic postures, such as prolonged neck extension and elevated arm positions during maintenance at heights of about 2 meters. This highlights the need for systematic posture assessment using OWAS and LEBA methods.

- Work Posture Data for Air Fin Cooler Maintenance Operators

Data on work postures of air fin cooler maintenance operators were collected through field observations and a Google Forms questionnaire distributed to 38 operators at PT XYZ. The OWAS method assesses four posture components: back, arms, legs, and load, each classified into coded categories to form a four-digit posture code. This code determines the action level, which indicates the ergonomic risk and urgency of corrective action [13].

Back posture is coded from 1 (upright) to 4 (bent and twisted), arm posture from 1 (below shoulder level) to 4 (both arms above shoulder level), leg posture from 1 (normal standing/sitting) to 4 (kneeling or frequent movement), and load from 1 (<10 kg) to 4 (>20 kg). Action levels range from Category 1 (safe) to Category 4 (immediate corrective action required). These classifications are based on observations and questionnaire results from each operator [14].

As show in figure 2 illustrates the OWAS method work posture assessment worksheet, which is used to classify workers' postures based on the position of the back, arms, legs, and the load handled, resulting in an action level that indicates the urgency of ergonomic improvements needed to reduce the risk of musculoskeletal disorders.

WORKSHEET PENILAIAN OWAS – AIR FIN COOLER PT. XYZ

Ovako Working Posture Analysis System | Operator Maintenance Air Fin Cooler

POSTUR PUNGGUNG (BACK)		POSTUR LENGAN (ARMS)		POSTUR KAKI (LEGS)	
Sangat baik (lurus/tegak)	1	Sangat baik (kedua tangan di bawah bahu)	1	Sangat stabil (berdiri normal/duduk)	1
Cukup baik (sedikit membungkuk)	2	Cukup baik (sesekali di atas bahu)	2	Cukup stabil (sedikit berpindah/tumpuan berubah)	2
Kurang baik (miring atau membungkuk jelas)	3	Kurang baik (satu tangan di atas bahu)	3	Kurang stabil (jongkok/bertumpu satu kaki)	3
Tidak baik (membungkuk dan miring)	4	Tidak baik (kedua tangan di atas bahu)	4	Tidak stabil (berlutut/sering berpindah)	4

BERAT BEBAN (LOAD/FORCE)	
Sangat ringan (< 10 kg)	1
Ringan (10 – 20 kg)	2
Berat (mendekati 20 kg)	3
Sangat berat (> 20 kg)	4

KODE POSTUR & ACTION LEVEL

Kode Postur (Punggung – Lengan – Kaki – Beban)			
1	1	2	2
Punggung	Lengan	Kaki	Beban

ACTION LEVEL → 1 – AMAN

KLASIFIKASI ACTION LEVEL OWAS	
1	Aman – Tidak perlu tindakan
2	Perbaikan mungkin diperlukan
3	Tindakan diperlukan segera
4	Tindakan segera secepatnya

REKAP PENILAIAN OWAS OPERATOR MAINTENANCE

Nama Operator	Kode Postur	Action Level (AL)	Keterangan
Iwan Kurniawan	1321	3	Tindakan diperlukan segera
Budi Santoso	2322	3	Tindakan diperlukan segera
Andi Pratama	2321	3	Tindakan diperlukan segera
Asep Saepuloh	3322	2	Perbaikan mungkin diperlukan
Dedi Kurniawan	1222	1	Aman

Figure 1. OWAS Method Work Posture Assessment Worksheet

- Assignment of Posture Codes and Determination of OWAS Action Levels

After the OWAS code is determined, the ergonomic risk level is identified using the OWAS action level table based on posture and load combinations. The resulting action levels are presented in the OWAS assessment worksheet [15].

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As show in figure 3 shows the OWAS action level matrix (Back × Arms × Legs), which is used to determine the level of ergonomic risk based on the combination of body postures, where each intersection produces an action category ranging from safe conditions to those requiring immediate corrective actions to prevent musculoskeletal disorders.

Back	Arms	Foot			
		1	2	3	4
1	1	1	1	1	2
	2	1	1	1	2
	3	1	1	2	2
	4	1	1	2	2
2	1	2	2	3	3
	2	2	2	3	3
	3	3	3	3	3
	4	3	2	3	4
3	1	2	3	4	4
	2	2	3	3	4
	3	2	2	3	3
	4	2	3	4	4
4	1	2	3	4	4
	2	3	3	4	4
	3	3	4	4	4
	4	4	4	4	4

Figure 3. OWAS Action Level Matrix (Back x Arms x Legs)

Calculations were performed to determine the OWAS code and action level for several representative respondents reflecting the range of risk levels identified in this study, including:

Respondent No. 1:

As show in figure 4 presents the OWAS action level matrix for Respondent No. 1, which shows the combination of back, arm, and leg postures resulting in an action level of 1, indicating that the working posture is classified as safe and does not require immediate corrective action, although periodic monitoring is still recommended.

Back	Arms	Foot			
		1	2	3	4
1	1	1	1	1	2
	2	1	1	1	2
	3	1	1	2	2
	4	1	1	2	2
2	1	2	2	3	3
	2	2	2	3	3
	3	3	3	3	3
	4	3	2	3	4
3	1	2	3	4	4
	2	2	3	3	4
	3	2	2	3	3
	4	2	3	4	4
4	1	2	3	4	4
	2	3	3	4	4
	3	3	4	4	4
	4	4	4	4	4

Figure 4. OWAS Action Level Matrix Respondent No. 1

Questionnaire data for respondent no. 1 (26 years old; maintenance type: lubrication and bearing replacement):

1. Back posture: “Very good (straight/upright)” score: 1
2. Arm posture: “Fairly good (occasionally above shoulder level)” score: 2
3. Leg posture: “Very stable (minimal shifting/weight-bearing changes)” score: 2
4. Load weight: “Light (10–20 kg)” score: 2

OWAS code: 1-2-2-2 (1222)

Based on the OWAS action level table, the code 1-2-2-2 corresponds to action level 1 (safe).

Conclusion: The work posture of respondent no. 1 is categorized as safe. Although the arms are occasionally raised above shoulder level, the load handled remains within the 10–20 kg range, and the back posture remains upright. No immediate action is required.

Respondent no. 5:

As show in figure 5 presents the OWAS action level matrix for Respondent No. 5, which shows the combination of back, arm, and leg postures resulting in an action level of 3, indicating that the working posture poses a high ergonomic risk and requires corrective actions to be implemented as soon as possible to prevent potential musculoskeletal disorders.

Back	Arms	Foot			
		1	2	3	4
1	1	1	1	1	2
	2	1	1	1	2
	3	1	1	2	2
	4	1	1	2	2
2	1	2	2	3	3
	2	2	2	3	3
	3	3	3	3	3
	4	3	2	3	4
3	1	2	3	4	4
	2	2	3	3	4
	3	2	2	3	3
	4	2	3	4	4
4	1	2	3	4	4
	2	3	3	4	4
	3	3	4	4	4
	4	4	4	4	4

Figure 5. OWAS Action Level Matrix Respondent No. 5

Questionnaire data for respondent no. 5 (age 29); maintenance type: lubrication, motor replacement, and bearing replacement.

1. Back posture: "Fairly good (slightly bent)" score: 2
2. Arm posture: "Poor (one arm above shoulder level)" score: 3
3. Leg posture: "Unstable (kneeling/frequent shifting)" score: 4
4. Load weight: "Light (10–20 kg)" score: 2

OWAS code: 2-3-4-2 (2342)

Based on the OWAS action level table, the code 2-3-4-2 corresponds to action level 3 (immediate action required).

Conclusion: The work posture of respondent No. 5 is categorized as hazardous and requires immediate corrective action. The combination of a stooped back, arms raised above shoulder level, and an unstable stance while replacing the motor poses a high risk of musculoskeletal disorders. The task of replacing the fin cooler fan motor requires the operator to lift heavy components while maintaining an unergonomic posture for a prolonged period.

Respondent no. 33:

As show in figure 6 presents the OWAS action level matrix for Respondent No. 33, which shows the combination of back, arm, and leg postures resulting in an action level of 2, indicating that the working posture has a moderate ergonomic risk and may require improvements in the future to prevent potential musculoskeletal disorders.

Back	Arms	Foot			
		1	2	3	4
1	1	1	1	1	2
	2	1	1	1	2
	3	1	1	2	2
	4	1	1	2	2
2	1	2	2	3	3
	2	2	2	3	3
	3	3	3	3	3
	4	3	2	3	4
3	1	2	3	4	4
	2	2	3	3	4
	3	2	2	3	3
	4	2	3	4	4
4	1	2	3	4	4
	2	3	3	4	4
	3	3	4	4	4
	4	4	4	4	4

Figure 6. OWAS Action Level Matrix Respondent No. 33

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Questionnaire data for respondent no. 33 (38 years old); maintenance type: lubrication, V-belt replacement, and bearing replacement.

1. Back posture: “Poor (clearly tilted/stooped)” score: 3
2. Arm posture: “Poor (one arm above shoulder level)” score: 3
3. Leg posture: “Fairly stable (slight shifting/change in weight-bearing)” score: 2
4. Load weight: “Light (10–20 kg)” score: 2

OWAS code: 3-3-2-2 (3322)

Based on the OWAS action level table, the code 3-3-2-2 corresponds to Action Level 2 (corrective action may be required).

Conclusion: Although the OWAS assessment indicates Action Level 2, the LEBA assessment for respondent no. 33 yields the highest score (21), placing it in the “Very High” category. This highlights the importance of using both methods complementarily, as OWAS does not fully account for duration and frequency factors, which are very high in this case.

- Analysis of OWAS Results and Formulation of Ergonomic Improvement Recommendations

Based on the OWAS assessment results in table 1, the distribution of action levels for all air-fin cooler maintenance operators at PT XYZ is presented in the following table.

As presented in Table 1, the distribution of OWAS action levels among Air Fin Cooler maintenance operators shows that most respondents fall under Action Level 1 (50%), indicating that their working postures are relatively safe and do not require immediate intervention. Meanwhile, 28.9% of the operators are categorized in Action Level 2, suggesting that improvements may be needed in the future. In addition, 21.1% are included in Action Level 3, which calls for prompt corrective measures. These findings suggest that although a large proportion of operators work under acceptable conditions, a considerable number are still exposed to moderate to high ergonomic risks.

Table 1. OWAS Action Level Distribution Air Fin Cooler Maintenance Operator

Action Level	Information	Number of Respondents	Percentage	Action
1	Safe	19 people	50%	Not required
2	Repairs may be needed	11 people	28,9%	Attention needed soon
3	Immediate action required	8 people	21,1%	Repair as soon as possible
4	Action required as soon as possible	0 people	0,0%	Repair immediately / stop
Total		38 people	100%	

Based on table 1, the results of the OWAS method analysis indicate that 19 operators (50%) fall under action level 1, meaning their work postures are categorized as safe and do not require immediate corrective action. A total of 11 operators (28.9%) were classified at action level 2, indicating that postural improvements are likely necessary. At this level, the company needs to take action by conducting routine evaluations, encouraging the adoption of more ergonomic work techniques, and considering near-term improvements to work facilities to prevent the situation from escalating into a higher-risk scenario. Meanwhile, 8 operators (21.1%) were at action level 3, meaning that postural corrections must be implemented immediately, as the non-ergonomic postures pose a potential risk of musculoskeletal disorders. Measures such as providing assistive devices, redesigning workspaces, or modifying work methods need to be adopted promptly to minimize the risk of injury to the operators. Notably, no operators in this study were found to be at action level 4.

Operators classified in Action Level 3 typically showed a combination of a bent or stooped back (code 2), arms positioned above shoulder height (code 3), and unstable leg postures. Such working conditions indicate the need for corrective actions to be carried out as soon as possible.

Proposed ergonomic improvements include providing work aids such as height-adjustable platforms and lifting equipment, implementing job rotation and periodic breaks, developing ergonomic standard operating procedures (SOPs), and providing ergonomic training for operators. Priority should be given to the 8 operators in Action Level 3,

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followed by the 11 operators in Action Level 2, to reduce the risk of Work-Related Musculoskeletal Disorders (WMSDs) [16].

➢ Data Processing Using the LEBA Method

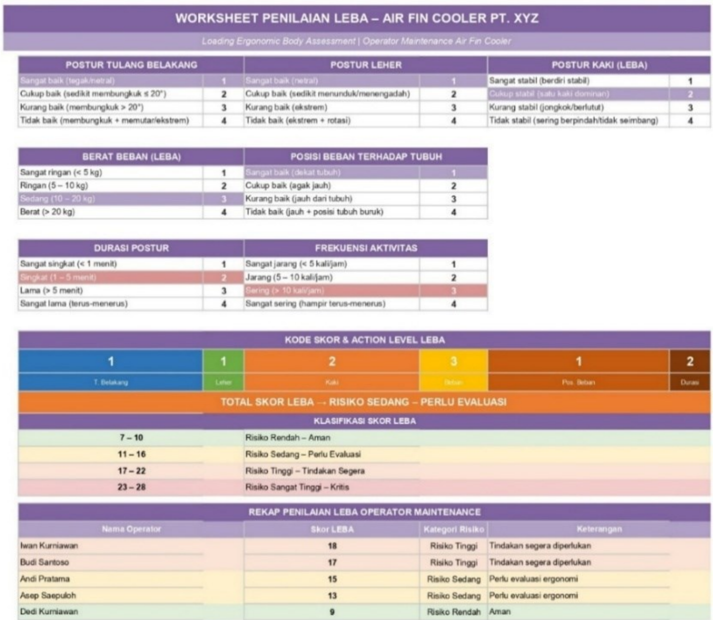
- Measurement of Body Posture, Workload, and Work Duration

Work posture analysis using the Loading on the Entire Body Assessment (LEBA) method is conducted by evaluating seven ergonomic aspects in an integrated manner: spinal posture, neck posture, leg posture, load weight, load position relative to the body, posture duration, and work activity frequency. Each aspect is scored based on established criteria, and these scores are summed to obtain the total LEBA score. Based on this total score, the work posture risk category is determined, comprising four levels: low (<7), moderate (8–12), high (13–17), and very high (>18) [17].

Spinal posture is scored as follows: 1 (upright/neutral), 2 (slightly bent <20°), 3 (bent >20°), and 4 (bent + twisting/extreme). Neck posture is scored: 1 (neutral), 2 (slightly tilted down/up), 3 (extreme), and 4 (extreme + rotation). Leg posture is scored: 1 (stable standing), 2 (one dominant leg), 3 (squatting/kneeling), and 4 (frequent shifting/unbalanced). Load weight is scored: 1 (<5 kg), 2 (5–10 kg), 3 (10–20 kg), and 4 (>20 kg). Load position relative to the body is scored: 1 (close to the body), 2 (somewhat distant), 3 (far from the body), and 4 (far + poor body position). Posture duration is scored: 1 (<1 minute), 2 (1–5 minutes), 3 (>5 minutes), and 4 (continuous without breaks). Activity frequency is scored: 1 (<5 times/hour), 2 (5–10 times/hour), 3 (>10 times/hour), and 4 (almost continuous).

As shown in figure 7, the LEBA method work posture worksheet is used to evaluate ergonomic risk based on body posture, load, duration, and activity frequency, resulting in a total score that indicates the level of musculoskeletal risk and the need for corrective action.

Figure 7. LEBA Method Work Posture Worksheet



WORKSHEET PENILAIAN LEBA – AIR FIN COOLER PT. XYZ

Loading Ergonomic Body Assessment | Operator Maintenance Air Fin Cooler

POSTUR TULANG BELAKANG		POSTUR LEHER		POSTUR KAKI (LEBA)	
Sangat baik (tegak/netral)	1	Sangat baik (netral)	1	Sangat stabil (berdiri stabil)	1
Cukup baik (sedikit membungkuk ≤ 20°)	2	Cukup baik (sedikit menunduk/menengadah)	2	Cukup stabil (satu kaki dominan)	2
Kurang baik (membungkuk > 20°)	3	Kurang baik (ekstrem)	3	Kurang stabil (jongkok/berlutut)	3
Tidak baik (membungkuk + memutar/ekstrem)	4	Tidak baik (ekstrem + rotasi)	4	Tidak stabil (sering berpindah/tidak seimbang)	4

BERAT BEBAN (LEBA)		POSISI BEBAN TERHADAP TUBUH	
Sangat ringan (< 5 kg)	1	Sangat baik (dekat tubuh)	1
Ringan (5 – 10 kg)	2	Cukup baik (agak jauh)	2
Sedang (10 – 20 kg)	3	Kurang baik (jauh dari tubuh)	3
Berat (> 20 kg)	4	Tidak baik (jauh + posisi tubuh buruk)	4

DURASI POSTUR		FREKUENSI AKTIVITAS	
Sangat singkat (< 1 menit)	1	Sangat jarang (< 5 kali/jam)	1
Singkat (1 – 5 menit)	2	Jarang (5 – 10 kali/jam)	2
Lama (> 5 menit)	3	Sering (> 10 kali/jam)	3
Sangat lama (terus-menerus)	4	Sangat sering (hampir terus-menerus)	4

KODE SKOR & ACTION LEVEL LEBA

T. Belakang	Leher	Kaki	Beban	Pos. Beban	Durasi
1	1	2	3	1	2

TOTAL SKOR LEBA → RISIKO SEDANG – PERLU EVALUASI

KLASIFIKASI SKOR LEBA

7 – 10	Risiko Rendah – Aman
11 – 16	Risiko Sedang – Perlu Evaluasi
17 – 22	Risiko Tinggi – Tindakan Segera
23 – 28	Risiko Sangat Tinggi – Kritis

REKAP PENILAIAN LEBA OPERATOR MAINTENANCE

Nama Operator	Skor LEBA	Kategori Risiko	Keterangan
Iwan Kurniawan	18	Risiko Tinggi	Tindakan segera diperlukan
Budi Santoso	17	Risiko Tinggi	Tindakan segera diperlukan
Andi Pratama	15	Risiko Sedang	Perlu evaluasi ergonomi
Asep Saepuloh	13	Risiko Sedang	Perlu evaluasi ergonomi
Dedi Kurniawan	9	Risiko Rendah	Aman

- Operator Work Posture Data Obtained via Questionnaire

The LEBA method also includes a classification of variable scores. The following table outlines the color classifications and codes used in the LEBA method:

As show in figure 7 (Table 2) presents the LEBA score classification for Variable 1 (spinal posture), which categorizes spinal positions based on the degree of bending and twisting, indicating increasing levels of biomechanical risk to the spine as the score rises.

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Table 2. Score classification for Variable 1 (LEBA): Spinal Posture

Score	Spinal Posture	Criteria
1	Upright / neutral	Spine in a neutral anatomical position without significant bending (0–10°)
2	Bending ≤ 20°	Mild to moderate spinal flexion, within tolerable limits
3	Bending > 20°	Spinal flexion exceeding 20 degrees; poses a risk of pressure on intervertebral discs
4	Bending + twisting	Simultaneous combination of flexion and rotation/lateral bending poses the highest risk to the spine

As shown in table 3, the score classification for LEBA Variable 2 (neck posture) categorizes neck positions based on the degree of flexion, extension, and rotation, indicating increasing levels of strain and musculoskeletal risk as the score increases.

Table 3. Score Classification for LEBA Variable 2: Neck Posture

Score	Neck Posture	Criteria
1	Neutral	Head in an upright position facing forward, without significant extension, flexion, or rotation
2	Mild flexion/extension	Slightly looking down or up (10–20°); common when inspecting components
3	Extreme flexion/extension	Deep flexion (>20°) or extreme extension (>20°) for prolonged periods; often occurs when the operator looks upward to install motor components
4	Flexion + lateral rotation	Combination of looking down/up while simultaneously turning the head to the side

As shown in table 4, the classification of LEBA variable scores (3–7) evaluates legs, load weight, load position, posture duration, and activity frequency, indicating increasing ergonomic risk as the scores rise, which helps determine the level of musculoskeletal risk and the urgency of corrective actions.

Table 4. Classification of LEBA Variable Scores (3–7): Legs, Load, Position, Duration, Frequency.

Score	S3: Leg Posture	S4: Load Weight	S5: Load Position	S6: Posture Duration	S7: Frequency
1	Very stable stance	< 5 kg	Close to the body	< 1 minute	< 5 times/hour
2	One dominant leg / reasonably stable	5–10 kg	Somewhat distant	1–5 minutes	5–10 times/hour
3	Squatting or kneeling	10–20 kg	Far from the body	> 5 minutes	> 10 times/hour
4	Unstable / frequently shifting position	> 20 kg	Very far + poor position	Continuous	Continuous

- Musculoskeletal Complaint Scores as Supporting Data for LEBA Analysis

Data processing regarding workers' musculoskeletal complaint scores was conducted to determine the severity of complaints in specific body regions, serving as supporting data for the LEBA analysis. Results from the Nordic Body

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Map demonstrated a correlation between body areas receiving high LEBA scores and those most frequently reported as sites of discomfort.

The neck area recorded the highest average LEBA score (S2 = score 2–3), consistent with Nordic Body Map findings showing that 100% of respondents reported complaints regarding the upper neck. The shoulder and upper arm areas received high LEBA scores for variable S2 (neck posture), a result closely linked to arm postures involving lifting above shoulder level. Significant strain on the lower back was observed, particularly among operators performing motor replacements while bent over for extended periods. This alignment confirms the validity of the LEBA method in comprehensively identifying risks of musculoskeletal disorders [18].

The total LEBA score is calculated by summing the scores from all seven variables, as follows:

$$\text{Total LEBA Score} = S1 + S2 + S3 + S4 + S5 + S6 + S7$$

Legend:

S1 = Spine

S2 = Neck

S3 = Legs

S4 = Load

S5 = Load Position

S6 = Duration

S7 = Frequency

As shown in table 5, the total LEBA score categorizes the level of ergonomic risk and determines the urgency of corrective actions required for each operator's working posture.

Table 5. Risk Category Based on Total LEBA Score

Score Range	Risk Category	Risk Level	Action	Description
≤ 7	Low (Safe)	Low	None required	Ergonomic posture and working conditions; no significant risk
8–12	Medium (May Require Attention)	Moderate	Observation	Risk factors present; monitoring and consideration of improvements required
13–17	High (Requires Improvement)	High	Rectify immediately	Significant risk of MSDs; ergonomic intervention required in the near future
≥ 18	Very High (Immediate Improvement Needed)	Very High	Urgent	Very high risk of MSDs; urgent and comprehensive ergonomic improvements required

There are also several detailed calculations of the total LEBA scores for representative respondents, as follows:

As shown in table 6, the LEBA score calculation for Respondent No. 1 results in a total score of 11, which falls into the moderate risk category, indicating that ergonomic improvements may be required and further observation is recommended to prevent potential musculoskeletal disorders.

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Table 6. LEBA Score Calculation for Respondent No. 1

LEBA Variables	Respondent's Answer	Score	Description
1. Spine (S1)	Very good (upright/neutral)	1	Spinal posture
2. Neck Posture (S2)	Very good (neutral)	1	Neck/head posture
3. Leg Posture (S3)	Very stable	1	Leg stability
4. Load Weight (S4)	Light (5–10 kg)	2	Load handled
5. Load Position (S5)	Very good (close to the body)	1	Distance of load from the body
6. Posture Duration (S6)	Prolonged (>5 minutes)	3	Duration posture is maintained
7. Frequency (S7)	Infrequent (5–10 times/hour)	2	Frequency of repetitive movements
Total LEBA Score	S1+S2+S3+S4+S5+S6+S7	11	Moderate (May Require Attention)

Calculation: Total Score = 1+1+1+2+1+3+2 = 11 (Moderate Category; May Require Attention)

Respondent No. 1 received a high score on the Duration variable (Score of 3) because the duration of the posture maintained during maintenance exceeded 5 minutes, even though the other variables were relatively favorable. This indicates that although the static body posture appears ergonomic, the factor of exposure duration still contributes a risk that warrants attention.

As shown in table 7, the LEBA score calculation for Respondent No. 6 results in a total score of 17, which falls into the high-risk category, indicating that immediate ergonomic improvements are required to reduce the risk of musculoskeletal disorders.

Table 7. LEBA Score Calculation for Respondent No. 6

LEBA Variables	Respondent's Answer	Score	Description
1. Spine (S1)	Very good (upright/neutral)	1	Spinal posture
2. Neck Posture (S2)	Poor (extreme)	3	Neck/head posture
3. Leg Posture (S3)	Unstable (frequently shifting/unbalanced)	2	Leg stability
4. Load Weight (S4)	Light (5 – 10 kg)	3	Load handled
5. Load Position (S5)	Fairly good (somewhat distant)	2	Distance of load from the body
6. Posture Duration (S6)	Prolonged (> 5 minutes)	3	Duration the posture is maintained
7. Frequency (S7)	Frequent (> 10 times/hour)	3	Frequency of repetitive movements
Total LEBA Score	S1+S2+S3+S4+S5+S6+S7	17	High (Needs Improvement)

Calculation: Total Score = 1+3+4+2+2+3+3 = 17 (High Category – Improvement Needed)

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Respondent No. 6 received high scores primarily in the variables of Neck Posture (Score 3), Free Weight (Score 3), Duration (Score 3), and Frequency (Score 3). This operator performs heavy maintenance requiring work at a height of ±2 meters, frequently tilting their head upward to inspect motor components located above the Air Fin Cooler unit.

As shown in table 8, the LEBA score calculation for Respondent No. 24 results in a total score of 21, which falls into the very high-risk category, indicating that immediate and comprehensive ergonomic interventions are urgently required to minimize the risk of severe musculoskeletal disorders.

Table 8. LEBA Score Calculation for Respondent No. 24

LEBA Variables	Respondent's Answer	Score	Description
1. Spine (S1)	Very good (upright/neutral)	1	Spinal posture
2. Neck Posture (S2)	Poor (extreme)	3	Neck/head posture
3. Leg Posture (S3)	Unstable (frequent shifting/unbalanced)	4	Leg stability
4. Load Weight (S4)	Heavy (> 20 kg)	4	Load handled
5. Load Position (S5)	Poor (away from the body)	3	Distance of load from the body
6. Posture Duration (S6)	Prolonged (> 5 minutes)	3	Duration the posture is maintained
7. Frequency (S7)	Frequent (> 10 times/hour)	3	Frequency of repetitive movements
Total LEBA Score	S1+S2+S3+S4+S5+S6+S7	21	Very High (Immediate correction)

Calculation: Total Score = 1+3+4+4+3+3+3 = 21 (Category: Very High – Immediate Improvement Required).

Respondent No. 24 is the operator with the highest total LEBA score in this study (21 out of a maximum of 28). Highly unstable l eg posture due to kneeling on scaffolding (Score 4), combined with a very heavy load a drive motor weighing over 20 kg (Score 4) as well as the load's position far from the body (Score 3), prolonged exposure duration (Score 3), and high frequency of repetitive movements (Score 3), place this operator at the highest ergonomic risk in the study.

- Risk Level Classification and LEBA Result Analysis

Based on the results of the LEBA method analysis presented in Table 4.20, the distribution of risk categories for all air fin cooler maintenance operators at PT XYZ is summarized in the following table.

As shown in table 9, most operators were classified as high risk (57.9%), followed by medium risk (26.3%) and very high risk (15.8%). No operators were categorized as low risk, indicating that all evaluated work postures require ergonomic attention.

Table 9. Risk Category Distribution: LEBA Method

Score	Category	Status	Amount	Percentage
< 7	Low	Safe	0	0%
8-12	Medium	May Require Repair	10	26,3%
13-17	High	Requires Repair	22	57,9%
> 18	Very High	Requires Immediate Repair	6	15,8%
	Total		38	100%

The LEBA results show that most operators are at risk: 57.9% in the high-risk category and 15.8% in the very high-risk category, while 26.3% are in the moderate category and none are low risk. The average score (14.6) indicates overall high risk, requiring ergonomic improvements, with urgent action needed for very high-risk postures.

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Operators falling into the "very high" category of the LEBA assessment typically perform heavy maintenance tasks at heights, involving unstable body postures, workloads exceeding 10 kg, prolonged work durations, and repetitive movements. These conditions indicate that the ergonomic risk associated with air fin cooler maintenance activities is quite high.

- Analysis of Risk Assessment Results and Ergonomic Improvement Recommendations Based on the LEBA Method

The results of the work posture risk assessment using the LEBA method indicate that this method provides a more comprehensive evaluation by directly accounting for work duration and frequency factors. Several operators previously classified as "Action Level 1" under the OWAS method were found to fall into the moderate-to-high risk categories under the LEBA method, due to long work durations and high-frequency repetitive movements. To mitigate the risk of musculoskeletal disorders among workers, the following ergonomic improvement recommendations have been formulated based on the LEBA assessment results:

1. The use of mechanical aids, such as hydraulic lifts or chain blocks, to reduce postural strain associated with variables S4 (load weight) and S5 (load position), thereby lowering the scores for both variables from 3–4 to 1–2.
2. Provision of a more stable and spacious scaffolding platform to reduce the S3 variable score (leg posture) from 4 (unstable) to 1–2 (stable standing).

C. Analysis and Discussion

The analysis of air-fin cooler maintenance operators' work postures using the OWAS and LEBA methods shows varying levels of ergonomic risk among 38 operators. Both methods complement each other in assessing posture-related musculoskeletal disorder (MSD) risks, and the findings are supported by the Nordic Body Map results.

The OWAS assessment results showed that 50% of operators (19 workers) were classified as Action Level 1 (safe), 28.9% (11 workers) as Action Level 2 (improvement may be needed), and 21.1% (8 workers) as Action Level 3 (high risk requiring immediate corrective action). Operators in the higher-risk category were generally involved in heavy maintenance tasks, particularly air-fin cooler motor replacement, which involved non-ergonomic working postures.

The task of replacing the fin cooler fan motor inherently involves non-ergonomic postures. Since the motor is located at the bottom of a machine standing approximately two meters tall, the operator is required to reach above shoulder height for extended periods while maintaining balance on limited scaffolding space. These conditions are difficult to avoid without altering the work design or utilizing mechanical aids.

The LEBA assessment yields a more comprehensive and conservative overview. The absence of operators in the low-risk category reflects the fact that even for maintenance tasks classified as safe under the OWAS method (action level 1) temporal factors such as the duration and frequency of postural exposure still contribute to the cumulative risk of musculoskeletal disorders (MSDs). This is particularly significant given that maintenance work involves long durations and a high frequency of repetitive movements [19].

A total of 57.9% of the operators fell into the "high" category, making it the dominant category in the study's respondent distribution. An analysis of scores by variable for this group revealed that the variables most frequently receiving high scores were: first, leg posture due to many operators working in unstable positions on scaffolding (scoring 3–4); second, posture duration as most maintenance activities lasted longer than 5 minutes (scoring 3); and third, activity frequency where repetitive movements such as tightening bolts, applying lubricant, and climbing up or down scaffolding occurred more than 10 times per hour (scoring 3).

Furthermore, six operators fell into the "very high" category with scores exceeding 18 indicating the highest level of risk or complaints compared to other categories; all were senior operators over the age of 30 who regularly performed heavy maintenance tasks. Their total LEBA scores ranged from 18 to 21, with leg posture and duration identified as the primary contributing variables. This situation is highly concerning, as epidemiological studies have shown that cumulative exposure to non-ergonomic postures involving heavy loads over extended periods is a major risk factor for the development of chronic musculoskeletal disorders [20].

D. Recommendations for Improvement

Based on the results of the work posture analysis using the OWAS and LEBA methods, ergonomic improvement recommendations have been formulated to mitigate the risk of musculoskeletal disorders for air fin cooler maintenance operators at PT XYZ, including:

1. Provide mechanical lifting aids such as hydraulic lifts, chain blocks, or mobile elevated work platforms (MEWPs) to reduce the need for operators to lift heavy components (>10 kg) with their hands positioned above shoulder height. This measure will directly lower the OWAS arm code from 3 to 1 or 2, and reduce the scores for variables S4 (load weight) and S5 (load position) in the LEBA assessment.
2. Replace or modify the existing scaffolding to create a wider, more stable work platform equipped with sturdy handrails. A more ergonomic scaffolding platform will enable the operator to stand stably, thereby changing the OWAS leg code from 6 to 2 and reducing the LEBA S3 score (leg posture) from 4 to 1–2.

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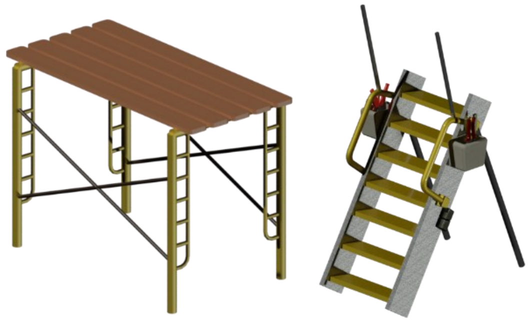
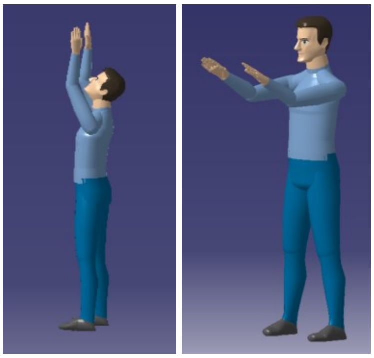
As shown in figure 2, the scaffolding was improved by incorporating an adjustable stair platform and equipment holder, enabling operators to work at an appropriate height while reducing excessive reaching and awkward postures.



(a) (b)

Figure 2. Scaffolding Before (a) and After (b) Innovation

As shown in figure 3, the operator's posture changed from an awkward overhead position before the improvement to a more comfortable and ergonomic posture after the assistive device was implemented.



(a) (b)

Figure 3. Illustration of the operator before (a) and after (b) the improvement of the assistive device.

3. Implement an active break program lasting 10–15 minutes every 40–60 minutes during maintenance activities. Active breaks should include stretching exercises for the neck, shoulders, back, and arms. This measure will directly reduce the score for the S6 variable (posture duration) in the LEBA assessment.
4. Conduct periodic ergonomics training or awareness sessions for all maintenance operators, covering safe working postures, correct manual lifting techniques, effective use of mechanical aids, and early recognition of musculoskeletal fatigue symptoms. Operators with good ergonomic awareness are better able to independently adjust their working postures.
5. Carry out periodic health check-ups focusing on the musculoskeletal system (neck, shoulders, upper arms, and back) for all maintenance operators, prioritizing those identified at Action Level 3 under the OWAS method or in the "very high" category under the LEBA method. Conducting these check-ups every six months will enable the early detection of musculoskeletal disorders (MSDs) before they progress into more serious conditions requiring long-term medical treatment.

Conclusion

OWAS assessment results for 38 operators indicated that 19 individuals (50%) were at action level 1 (safe), 11 (28.9%) at action level 2 (corrective action possibly required), and 8 (21.1%) at action level 3 (corrective action required soon), with no operators falling into action level 4. The highest-risk posture was observed during the drive motor replacement activity (OWAS code 2362), resulting in action level 3 due to a combination of a bent back, arms raised above shoulder level, and unstable footing on scaffolding at a height of approximately 2 meters. The LEBA assessment revealed more concerning conditions, with no operators falling into the low-risk category; 10 operators (26.3%) were in the moderate category, 22 (57.9%) in the high category, and 6 (15.8%) in the very high category, yielding an average total score of 14.6, which falls within the high-risk range. Leg posture, task duration, and work frequency were the primary contributors to the high LEBA scores, consistent with Nordic Body Map results showing that the most frequent complaints involved the neck, shoulders, and upper arms. Based on these findings, proposed ergonomic improvements include the use of mechanical aids such as hydraulic lifts and chain blocks, the provision of more stable scaffolding, the implementation of 10–15 minute active breaks every 45–60 minutes, job rotation among operators, periodic ergonomics training, and musculoskeletal health check-ups every six months, prioritizing high-risk operators.

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