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LEAN ERGONOMIC APPROACH TO ERGONOMIC RISK ANALYSIS FOR WORKPLACE ASSESSMENT

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Abstract. IKM NN Aluminum is a metal foundry that produces woks. Based on observations, it appears that the moulding workstation has the highest workload as the operators work in a standing position for 8 hours a day. In addition, the operator lifts a 35 kg mould. This results in un-ergonomic working postures such as excessive bending, head bending and twisting of the body, resulting in waste that has the potential to cause fatigue, physical injury and health problems. The aim of this study is to identify the factors that can cause motion waste, to assess the posture of workers during frying pan moulding activities and to analyse the health implications of the posture assessment. The approach used in this research is lean ergonomics, which combines the principles of lean manufacturing and ergonomics to identify and reduce waste. The methods used are process flow maps to determine the flow of production activities, REBA to identify non-ergonomic postures, and smartwatches for heart rate monitoring to measure worker fatigue. Based on the results of the study, the factor causing motion waste at the moulding workstation is due to the size of the frying pan moulding tool, whose height does not match human anthropometry. Work activities at the moulding station have a high REBA score of 11, which has the potential to cause occupational musculoskeletal disorders. The Pearson correlation test showed a significant relationship between the REBA score and the fatigue level of the workers as measured by heart rate.

Keywords : Lean Ergonomics, Postur Kerja, REBA (Rapid Entire Body Assesment), Waste of Motion

1. INTRODUCTION

The design of work systems in the manufacturing industry is very useful in creating a comfortable, effective and efficient work system, so it is very influential in increasing the quantity and quality of labour productivity in the industrial world [1]. Within the manufacturing industry, some things that need to be done are how to determine efforts to increase production efficiency, product quality and employee welfare. A job is considered to be done effectively and efficiently if it can be completed in a short time. In the production process, waste often occurs in various work activities. This waste can occur in the use of resources in the form of energy, human resources and time, making the production process ineffective and inefficient. This can lead to a decrease in worker performance. Some factors that contribute to improving performance are working conditions, motivation, work systems, effectiveness and efficiency at work [2].

There are several ergonomic approaches that can be used to minimise waste, one of which is lean ergonomics, which is a branch of science that can combine lean thinking with ergonomic approaches [3]. Lean thinking is achieved through the concept of Toyota Production System (TPS) thinking used by the Toyota company. According to the Toyota Production System (TPS) there are 7 wastes, namely overproduction, waiting, transportation, defects, inventory, overprocessing and motion. The main goal of lean thinking is to maximise productivity [4]. Lean ergonomics is about eliminating activities and improving the system to fit the principles of ergonomics [5]. When the principles of ergonomics are not in accordance with the system or the activities performed, it is called ergonomic waste. In lean ergonomics there are two types of waste, transport waste and movement waste. Ergonomics plays an important role in achieving the goal of minimising waste and errors and improving quality by reducing the number of excessive movements and the frequency of repetition, thus saving time and money [6].

One of the manufacturing companies that needs to apply the concept of lean ergonomics is IKM NN Aluminum. The company is involved in metal casting and produces products in the form of frying pans. From the survey results it is known that the workers work for 8 hours a day, from 07.00 to 15.00 WIB, with a break from 11.30 to 12.30 WIB. Although the company has a high production level, the efficiency and health of the employees must be taken into account. The production process at IKM NN Aluminum consists of seven stages, namely melting raw materials, forming, grinding, turning, smoothing and applying labels. Based on initial observations at all workstations, it was found that the moulding workstation has the highest workload, with operators working in a standing position for 8 hours a day. In addition, the operator lifts 35 kg of mould weight.

Un-ergonomic body movements such as excessive bending, head tilting and twisting were also found in frying pan moulding. This can lead to fatigue, physical injury and ongoing health problems. According to the National Institute for Occupational Safety and Health (NIOSH), the recommended weight considered safe for ideal lifting is 23kg, while for prolonged standing, the body can only tolerate standing for 20 minutes. Beyond this limit, tissue elasticity decreases, muscle strain increases and back discomfort occurs [7]. The results of interviews with several workers at the frying pan moulding workstation showed complaints of fatigue and pain in the arms, shoulders, back and legs with non-ergonomic postures. Therefore, there is a need for further identification of movement waste at IKM NN Aluminum. This research is expected to provide recommendations for improving the comfort of the workplace by applying lean ergonomic concepts to minimise activities and systems that are not in accordance with ergonomic principles. The identification of motion wastage will be carried out in the frying pan moulding process as a basis for analysing the impact of posture assessment on body health. Methods used include the Process Flow Map to determine the flow of frying pan making activities, the Rapid Entire Body Assessment (REBA) method to identify non-ergonomic postures, and smartwach to monitor workers' heart rate during work activities to determine the level of fatigue or physical stress experienced.

2. METHODS

This research was conducted at IKM NN Aluminum, a metal foundry located in Sorosutan Village, Yogyakarta. The research was conducted on workplace conditions, work environment, work posture, and potential ergonomic risks to workers' health. Observations were made at all workplaces and all workers were interviewed without sampling.

2.1. Data Collection Method

Data is collected by direct observation to map the overall process flow, measure the working environment such as temperature, noise, lighting, humidity and dust, and identify potential ergonomic risks. Data was collected using video and observed in slow motion to determine correct posture. Fatigue was measured for all workers using heart rate from a smartwatch. Pulse data from the heart rate can be used to determine whether a person is tired or normal. All workers were also asked to complete the SNQ questionnaire to find out about any complaints about parts of the body while working.

2.2. Research Design

The research was carried out using data collection stages as shown in Figure 1, starting with process flow mapping, measuring the work environment, distributing SNQ (Standard Nordic Questionnaire) questionnaires, videotaping work postures, identifying ergonomic risks, assessing ergonomic risks and making suggestions for workplace improvements. Based on the proposed improvements, efficiency was obtained from improving work posture. Improving work posture can reduce energy use during activities so that it can reduce fatigue levels.

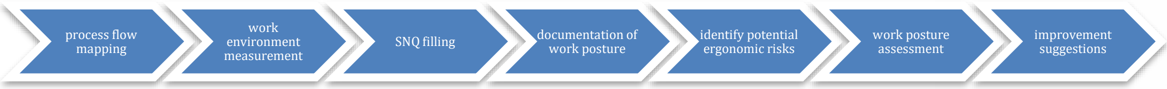

Figure 1. Research Design

2.3. Data Analysis

In this research, data analysis was carried out based on the results of data processing. This included:

a. Analysis of the SNQ (Standard Nordic Questionnaire) questionnaire to find out about complaints about workers' body parts.
b. Workplace analysis, to see how well the work equipment matches the needs of the production process carried out at each workstation.
c. Work environment analysis, to see the work environment conditions such as temperature, noise, vibration, humidity, dust and lighting [8].
d. Work posture analysis, to identify the awkward postures of the workers according to the work carried out using the REBA method [9].

e. Analysis of the results of ergonomic risk identification and assessment as a basis for workplace improvements
f. Te Testing the influence between the REBA score results and the average heart rate. In this study, a Pearson correlation test was conducted, aiming to see the relationship between the independent variables and the dependent variables. Before conducting a correlation test, it is necessary to conduct a classical assumption test, namely the normality test and the linearity test. [10], [11], [12].

3. RESULTS AND DISCUSSION

3.1. Operator and employee demographics

In the frying pan production process there are 10 printing workstations with 1 worker each, with male gender, average worker age 41.20 ± 9.11 years, average worker height 163 ± 5.55 cm, average worker body weight 56.30 ± 9.30 kg. Full demographic data can be found in Appendix 2. During production, workers at the printing station perform work in a static standing position for 7 hours of work, respondent data are presented in Table 1.

Table 1. Employee Demographics

No	Demographic data	N (%)	Mean±Sd	Min	Max
1	Gender				
	Male	10 (100)			
	Female	0 (0)			
2	Age		41,20 ± 9,11	21	55
3	Height		163 ± 5,55		
4	Weight		56,30 ± 9,30		
5	Type of work				
	Moulding wok	10 (100)			

3.2 Working Method

a. Tools/Machines: The production process of making pans at the molding work station uses a mold made of clay and a mold clamp made of wood. To release the mold hook requires strong force because the weight of the wooden hook is 15 kg. Other equipment used to smooth the pans are grinders and lathes.
b. Working environment: In the frying pan production room, the room temperature is 37˚C. The production room consists of several rooms, namely the melting and moulding room, the turning room, the grinding and filing room, the sticker application and quality control room, and the polishing room. At each work station there is a pile of frying pans that will be processed by the next work station.
c. How it works: The frying pan production process at the molding station begins with pouring molten aluminum into the mold, then letting it sit for a few minutes to flatten the mold. After being removed from the mold, the next step is to smooth it using a lathe and grinding machine.

3.3 Heart rate (HR) analysis

During activities at the printing workstation, the average heart rate (HR) for all workers was 128 bpm. The highest heart rate was 130 bpm and the lowest was 123 bpm. Table 2 below shows the overall average heart rate of the workers.

Table 2. Worker Heart Rate Summary

Worker	Age	Heart Rate
		Mean
Worker 1	21	123
Worker 2	43	128
Worker 3	42	127
Worker 4	42	126
Worker 5	55	130
Worker 6	48	129
Worker 7	29	124
Worker 8	35	125
Worker 9	53	129
Worker 10	49	128

From the heart rate results above, it can be seen that according to Astrand & Rodahl, based on existing HR measurement theory on a theoretical basis, the standard mean heart rate of 112-132 bpm is classified as heavy work [13]. This may be due to a number of factors, such as a high room temperature of 37°C and work activities that involve lifting weights, continuous movement and continuous work. This is in line with research conducted by Artayasa which stated that the average pulse rate of coconut transport workers was 126.24 ± 14.10 bpm which is also classified as heavy work [14]. Fatigue will quickly arise due to monotonous work, heavy and long-lasting physical work, poor microclimate, mental and psychological problems, illness, pain at work and lack of energy.

According to the American Heart Association, there are several factors that can influence an increase in heart rate, including the outside temperature and the intensity of the activity being performed. According to the Republic of Indonesia KEPMENKES concerning Health Requirements for Office and Industrial Work Environments, the temperature that meets the requirements for an industrial work environment is in the range of 18-30°C. High temperatures can affect heart rate because the body has to work harder to maintain its internal temperature, increasing the strain on the cardiovascular system.

From the heart rate data above it can be seen that the physical factors influencing the heart rate include the age of the worker. Worker 1, Worker 7 and Worker 8 are workers aged 23-35 years who have a better resistance to physical stress compared to Worker 2, Worker 3, Worker 4, Worker 5, Worker 6, Worker 9 and Worker 10 who are workers aged 42 -55 years. This is because the capacity of the heart and circulatory system decreases with age. This is also in line with research conducted by Akbar showing that nurses over 40 years old have a lower heart capacity, so they tend to have a higher heart rate compared to nurses under 40 years old [15].

3.4 Waste of Movement

Waste of movement data was collected by direct observation at IKM NN Aluminum. Table 3 shows the waste data collected at the wok printing workstation:

Tabel 3. *Waste Of Motion Idenification*

No	Process	Waste	Description	Cause
1	O-3 : opening wood on aluminum mold	Motion	The back and neck are too bent, the posture changes and the legs are not properly supported.	When opening the frying pan mould, the worker has to bend down to reach the handle. When bending down, the posture twists and there is a rapid change in position from the bent position where the legs support the body to maintain balance.
2	O-3 : Opening the aluminium moulding	Motion	Upper arm posture forms a large angle and excessive weight load	This process takes place when the worker opens the frying pan mould, where the worker grabs the 35 kg frying pan mould and crosses his arms to open and lift it.
3	O-4 : Smooth out the sides of the frying pan	Motion	The body posture is too bent and one leg is supporting the body.	During the levelling process, the worker has to bend down to see and level the required parts. This causes the back and neck to be bent too far, and the worker's feet are not properly supported or one leg is lifted to maintain body balance..
4	O-4 : Smooth out the sides of the frying pan	Motion	The upper arm posture forms a large angle	The worker holds the side of the frying pan to be flattened by applying pressure to ensure the surface of the frying pan is flat.
5	T-6 : Moving the pan to another place	Motion	Unergonomic posture of body and legs bent	Workers have to bend and stoop to see the side of the pan and then move it.
6	T-6 : Moving the pan to another place	Motion	A large angle is formed on the upper arm	When moving the pan to another place, the worker's hand is raised to put the pan down, causing the hand position to become tense.
7	T-7: Place the lid on the mould of the frying pan	Motion	Unergonomic body posture	When lifting and placing the 35 kg rying fpan molder, there is a change in posture from a straight back to a hunched back. The worker's neck is bent too far, and the hands are in a tense position, forming too large an angle to ensure the pan lid is properly closed.

No	Process	Waste	Description	Cause
8	0-3, 0-4, T-6, dan T-7	Motion	Potential for musculoskeletal injuries (MSDs)	During the work process which lasts for 8 hours, with the work being done while standing and with a non-ergonomic body posture.

3.5 Work posture assessment using the REBA method

Posture assessment is essential for identifying the risk of musculoskeletal disorders (MSDs) in different work environments. The Rapid Entire Body Assessment (REBA) method is used to identify the whole body posture and provide a risk score to assist in decision making for ergonomic improvements. Figure 2 shows the measurement of the worker's postural angle and Figure 3 shows the assessment score using REBA.

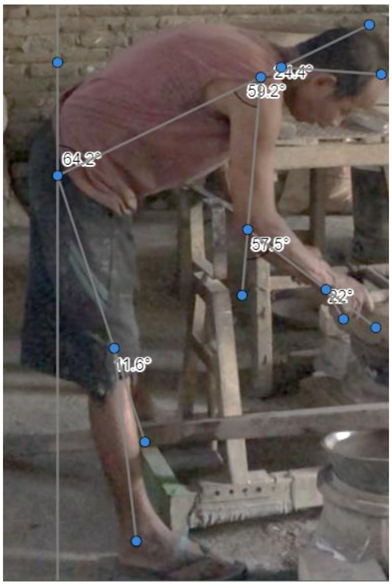

Figure 2. Measurement of Worker Posture

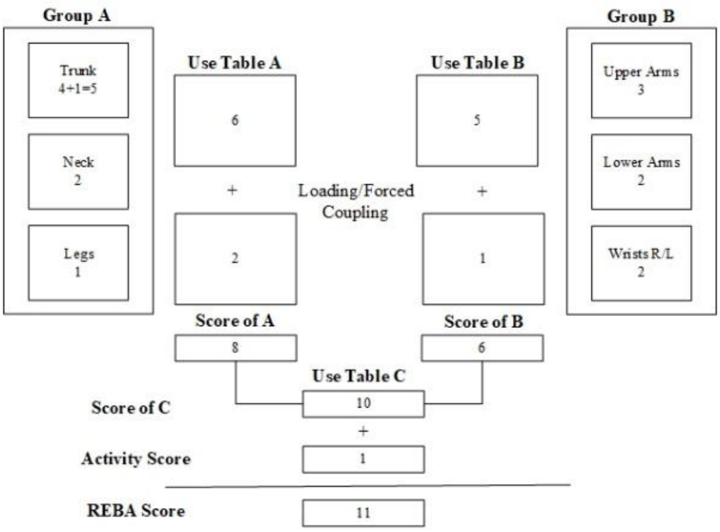

Figure 3. The Calculation of The REBA Score

As shown in Figure 3, the calculation of the REBA score follows the guidelines of the REBA Employee Assessment Worksheet.

a. Grup A

The posture forms an angle of 64.2˚, worth +4 because the flexion is over 60˚, plus +1 because the posture turns sideways while working.

The position of the neck forms an angle of 24.4˚, worth +2 because the flexion is >20˚. The position of the feet forms an angle of 11.6˚, worth +0, and the position of the feet is well supported, worth +1. The force or load the worker is lifting is >22 lbs, worth +2. This gives a Group A score of 8.

b. Grup B
The position of the upper arm forms an angle of 59.2˚, with flexion between 46˚ - 90˚, which is +3. The forearm position forms an angle of 59.2˚, with flexion <60˚, which is +2. The wrist position forms an angle of 22˚, with wrist flexion >15˚, which is +2. If the coupling is in the fair category, the score is +1. The score for group B is therefore 6.

c. Skor C
The result of the calculation of the scores for Group A and Group B was a score of 10.

d. Skor REBA
During work activities, there is a rapid change in posture, so an additional score of +1 is given. The REBA score obtained is therefore 11.

According to the National Institute for Occupational Safety and Health, the classification of semi-direct methods based on the cause of MSDs includes the use of REBA to identify strained postures. Research shows that unergonomic postures can lead to wasted movement and increased risk of injury. Wardhani uses REBA to identify postures in activities that cause wasted motion in the core assembly process. The following is an identification of worker postures using the REBA method [5]. Summary of REBA assessment results can be seen in the Table 4.

Table 4. REBA Score Recapitulation

Worker	Group A Scores	Body Angle	Neck Angle	Leg Angle	Group B Scores	Upper Arm Angle	Lower Arm Angle	Wrist	Group C Scores	Aktivity Score	REBA Score	Risk Level
Worker 1	7	47,4	28,5	14,7	6	48,4	12	22,8	9	1	10	High
Worker 1	7	55,1	23,6	1,2	6	59	75,5	72,8	9	1	8	High
Worker 1	5	52,9	19,8	13,7	3	27,7	87	59	4	1	5	Medium
Worker 1	7	57,5	25,9	6	4	37,3	55	35,3	8	1	9	High
Worker 2	7	54,2	27,7	12	6	57,4	28,2	39,4	9	1	10	High
Worker 2	6	71,1	17,1	20,3	6	20,3	45,2	65,3	8	1	9	High
Worker 2	5	57,2	17,7	5,1	6	80,6	35,9	27,7	7	1	8	High
Worker 2	7	53,6	22	10,7	6	48,7	59,3	40,4	9	1	10	High
Worker 3	8	44,3	26,9	26,9	4	31,8	27,5	22,9	9	1	10	High
Worker 3	7	47	35,1	40	4	41,1	24,5	33,8	10	1	9	High
Worker 3	8	72,3	34,1	23,4	5	51,4	87,5	42,9	10	1	11	Very High
Worker 3	8	66,9	32,4	27,4	6	56,8	42,7	30,8	10	1	11	Very High
Worker 4	7	50,5	32,7	17,4	4	41,2	28,2	23,3	8	1	9	High
Worker 4	7	56,5	26,7	23,7	4	39,1	26,5	44,1	8	1	9	High
Worker 4	7	51,7	32,4	14,3	6	62,7	58,2	33,5	9	1	10	High
Worker 4	7	58,8	30,6	13,5	6	56,8	43,7	27,4	9	1	10	High
Worker 5	9	37,3	23,7	33,2	4	40,7	25,9	25,9	10	1	11	Very High
Worker 5	7	41,5	25,9	11,7	6	50	67,3	23,3	9	1	10	High
Worker 5	7	50,4	23	6,6	4	36,5	58,4	22	8	1	9	High
Worker 5	8	64,2	28,5	11,6	26	59,2	33,7	32,8	10	1	11	Very High
Worker 6	7	25,7	21,6	19,8	3	17,8	12,5	33,5	7	1	8	High
Worker 6	8	65,2	26	17,8	6	78,4	52,5	35,3	10	1	11	Very High
Worker 6	7	46,7	26,4	3,4	4	37,6	54,7	35	8	1	9	High
Worker 6	7	46,6	32,7	5	4	37,3	31,9	31,7	8	1	9	High
Worker 7	8	57,1	31,5	30,8	4	44,1	22,3	29	9	1	10	High
Worker 7	8	62,5	33	29,6	6	82,2	42,2	45,6	10	1	11	Very High
Worker 7	8	42,1	30,5	14	6	58,5	45,7	38	10	1	11	Very High
Worker 7	7	46,1	33,7	19,9	4	52,8	19,5	29,4	9	1	10	High
Worker 8	9	39,9	33,3	50,2	4	35,4	15,5	31,2	10	1	11	Very High
Worker 8	7	65,2	26,7	24,7	4	41,1	31,6	58,2	9	1	9	High
Worker 8	7	52,5	27,2	2,2	3	17,4	93,2	18,7	7	1	8	High
Worker 8	7	45,3	55,2	7,2	4	38,8	33,5	24	8	1	9	High
Worker 9	9	68,3	30,2	19,3	6	77,5	42,3	29,9	10	1	11	Very High

Worker	Group A Scores	Body Angle	Neck Angle	Leg Angle	Group B Scores	Upper Arm Angle	Lower Arm Angle	Wrist	Group C Scores	Aktivity Score	REBA Score	Risk Level
Worker 9	6	79,7	19,9	26,4	6	84,6	51,3	42,7	8	1	9	High
Worker 9	8	61,2	25,2	15,9	3	61,9	84,8	34,3	10	1	11	Very High
Worker 9	8	71,5	22	19,2	6	86,3	51,9	29,2	10	1	11	Very High
Worker 10	7	48,4	33	21	6	49,6	23,3	21,4	9	1	9	High
Worker 10	8	63,7	22,5	14,5	6	58,4	75,8	36,4	10	1	11	Very High
Worker 10	7	48	28,3	14,6	5	61,3	63,1	28,2	9	1	10	High
Worker 10	7	48,9	25,5	9,5	6	52	27	26,7	9	1	10	High

After identifying all the postures reported as wasteful, the next step is to identify the postures of the work activities that cause wasteful postures by calculating the REBA score of 200 work activities performed by 10 workers at the printing workstation. The lowest score obtained was 5, with a moderate risk category requiring action, found in 5 work activities with a percentage of 3%. In addition, scores of 8, 9 and 10, which are in the high risk category and require immediate action, were found in 158 work activities with a percentage of 79%. The highest score was 11, which is in the very high risk category and requires immediate action, found in 37 work activities with a percentage of 19%.

This is in line with the findings of Johanes who stated that after obtaining the score and analysing it using the REBA method, the REBA activity score indicates a high risk in the operator's work posture, which requires immediate corrective action [16]. If left untreated, this will cause pain over a period of time and may lead to WRMDs (work-related musculoskeletal disorders), which is a group of musculoskeletal disorders involving muscles, tendons and nerves caused by material handling work.This needs to be done immediately as there is a fear that workers will experience musculoskeletal disorders.

The parts of the body at risk and showing signs of musculoskeletal disorders are the trunk, neck, legs and upper arms when working at the moulding workstation.

a. Open the frying pan molding
In the activity of opening the frying pan mould, the most risky back angle is for worker 9 with an angle of 68.3˚. The most risky neck angle is for worker 8 with an angle of 33.3˚. The most risky leg angle is for worker 8 with an angle of 50.2˚ and the most risky upper arm angle is for worker 9 with an angle of 87.4˚.

b. Smooth out the sides of the frying pan
In the activity of levelling the frying pan, the most risky back angle is found for worker 9 with an angle of 82.5˚. The most risky neck angle is for worker 3 with an angle of 35.1. The most risky leg angle is for worker 3 with an angle of 40˚ and the most risky upper arm angle is for worker 9 with an angle of 84.6˚.

c. Moving the frying pan
In the activity of moving the frying pan, the riskiest back angle is for worker 3 with an angle of 72.3˚. The riskiest neck angle is for worker 3 with an angle of 34.1˚. The riskiest leg angle is for worker 3 with an angle of 23.4˚ and the riskiest upper arm angle is for worker 2 with an angle of 80.6˚.

d. Place the lid on the mould
In the activity of closing the pan, the most risky back angle is found for worker 9 with an angle of 71.5. The most risky neck angle is found for worker 8 with an angle of 55.2. The most risky leg angle is found for worker 4 with an angle of 58.8˚ and the most risky upper arm angle is found for worker 9 with an angle of 86.3˚.

From From the results of the angle obtained, it can be seen that the worker is in a hunched position. The normal position of the spine should be kyphosis in the thorax and lordosis in the lumbar spine, and not tilted to the left or right. The hunched posture should not be more than 20 degrees, as the tissues in the back are normally loose in a neutral upright posture. Any posture that is not neutral will cause discomfort if done for a long time [17].

There is also a high-risk angle in the neck that causes workers to lean forward. According to Salsabila's research, a forward-leaning head posture can cause chronic pain, numbness in the arms and palms, improper breathing and pinched nerves [14]. In the legs, workers work in a standing position, using one or two feet for support. In the case of workers standing for long periods of time (static standing with minimal movement), it can result in work injuries, even standing for long periods of time causes physiological discomfort, muscle fatigue, pain and can also contribute to the development of serious health hazards such as Musculoskeletal Disorders (MSDs) with a particular focus on areas such as the back, legs and soles of the operator's feet [18].

On the other hand, according to Anggrianti, prolonged standing causes muscle contractions that block smooth blood circulation and cause blood reflux (blood pooling and static in the swollen vessels). Workers at the printing station stand for 8 hours and are constantly exposed to static loads. The upper arm develops a large shoulder angle, which increases the risk of injury [19].

Based on the identification of motion waste and the REBA score analysis, it can be seen that the motion waste at the printing workstation is caused by the height of the workstation, which does not comply with ergonomic standards. This condition forces workers to adopt a posture with excessive angles in the body, neck, legs and upper arms. As a result, the REBA score increases because workers have to bend over, the neck is too low, the upper arms are too open and the leg posture is not well supported, all of which increase the risk of fatigue, discomfort and injury to workers.

3.6 Statistical Test

Three statistical tests are used to test the data, namely the normality test, the linearity test and the Pearson correlation test. The results are explained as follows.

1. The Normality Test
   The normality test aims to determine whether or not the data used are normally distributed. In this case, the normality test was carried out using SPSS software and the Kolmogorov-Smirnov method. Based on the results of the normality test, the significance value is known to be 0.200. Since 0.200> 0.05, it can be concluded that the REBA score and the heart rate data of the workers are normally distributed, so that the conditions for carrying out the Pearson correlation test are met.
2. The Linearity Test
   The linearity test aims to determine whether the relationship between two variables is linear. Linearity is an important prerequisite for conducting a Pearson correlation test, as Pearson correlation is only relevant for linear relationships. The linearity test was performed using SPSS software. From the results of the linearity test, the deviation from linearity sig. value is 0.706. As the deviation from linearity sig. > 0.05, it can be interpreted that there is a linear relationship between the REBA score data and the worker's heart rate, thus meeting the requirements for performing a Pearson correlation test. Calculations were also made by comparing the calculated F and the F table. If the calculated F is 0.467 and the F table is 2.65, because the calculated F < F table, then the relationship can be accepted as linear.
3. Uji Korelasi Pearson
   The Pearson correlation test is used to measure the strength and direction of the linear relationship between two variables. Before performing this test, it is necessary to ensure that the data are normally distributed and that the relationship between the variables is linear. In this case, the Pearson correlation test was carried out using SPSS software.
4. The hypothesis of this study is as follows:
   H0: There is no relationship between REBA values at the printing workstation and workers' heart rates.
   H1: There is a relationship between the REBA values at the printing workstation and the heart rate of the workers.
   It is known that the significance value is 0.002 and the alpha significance value is 0.01. The Pearson correlation value is 0.22 and the Pearson correlation table value is 0.138. Based on these values it can be seen that H0 is rejected, which means that there is a significant relationship between the REBA values and the heart rates of the workers. The Pearson correlation value of 0.22 indicates that the relationship is weakly positive. The coefficient of determination (R squared) is 0.049 (4.9%), indicating that the heart rate factor has a small contribution to REBA.

3.7 Analysis of the Relationship between Rapid Entire Body Assessment (REBA) Scores and Heart Rate (HR)

The relationship between Heart Rate (HR) and Rapid Entire Body Assessment (REBA) exists because both provide information about the physical demands placed on workers. HR measures the level of physical fatigue, while REBA assesses posture, the load lifted and the type of activity to identify ergonomic risks. Jobs with high REBA scores tend to involve uncomfortable postures or heavy physical loads, which can increase HR. For example, jobs that require bending or repeatedly lifting a 35 kg printer load can result in a high REBA score and increase HR because the body has to work harder to maintain the posture.

Combining HR and REBA data provides a comprehensive picture of fatigue and injury risk. In short, HR and REBA are related because they measure different aspects of the physical strain experienced by workers. Jobs with high ergonomic risk (high REBA scores) tend to increase HR, so a combined analysis of the two provides better insight into how to improve working conditions. Below is a comparison of the REBA data with the highest scores and workers' heart rates. This is consistent with the study by Yassierli et al. (2016), which also found a significant relationship between work fatigue, measured by heart rate, and ergonomic risk assessment using REBA in specific groups of workers. This study suggests that the results of ergonomic risk assessments can be used as a basis for implementing ergonomic interventions to reduce the fatigue experienced by workers. Recommendations for good working postures can also reduce muscle strain, which contributes to fatigue in workers.

4. CONCLUSION

Based on the research that has been conducted, the following conclusions can be drawn:

a. The factor causing waste of motion at the frying pan printing workstation at IKM NN Aluminum is the height of the printing workstation which does not comply with ergonomic standards..

b. Un-ergonomic postures, such as excessive bending, too deep a lowering of the head, and improper body movements during the moulding process can cause fatigue and risk of physical injury to workers. In addition, the Lean Ergonomics analysis identified wasteful movements in the process that can affect worker productivity and health. Heart rate monitoring showed that workers had an average heart rate of 126,52 bpm, indicating a high physical workload due to un-ergonomic working postures. According to Seravalle & Grassi, a normal heart rate is 60–80 beats/minute with the exception of no history of disease, in healthy and trained subjects it is less than 50 beats/minute while in inactive subjects it is greater than 85 beats/minute [20].The Pearson correlation test confirmed a positive relationship between REBA scores and heart rate, indicating that the worse the posture, the greater the physical fatigue experienced by the workers.

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6. REFERENCES

[1] Sofani, I. S., Tanjung, Y. W. T., Kurnia, H. K., Ningrum, I. P. N., & Saputro, R. N. S., "Tinjauan Sistematik Pada Perancangan Sistem Kerja Di Industri Manufaktur Indonesia. Journal of Industrial and Engineering System," *3*(2), 179-186,2012.

[2] Wahyudi, W., Semmaila, B., & Arifin, Z., "Influences of work discipline, motivation and Working Environment Non physical on Civil apparatus Performance," Point Of View Research Management, 1(3), halaman 1-8, 2020.

[3] Toyota Production System – Toyota Motor Manufacturing Indonesia, https://www.toyota.co.id/industrial/tps, diakses pada tanggal 28 mei 2024.

[4] Lestari, K., & Susandi, D., "Penerapan Lean Manufacturing untuk mengidentifikasi waste pada proses produksi kain knitting di lantai produksi PT. XYZ," In Prosiding Industrial Research Workshop and National Seminar (Vol. 10, No. 1, pp. 567-575), 2019.

[5] Wardani, N. P., Septiani, W., & Safitri, D. M., "Lean Ergonomics Untuk Perbaikan Proses Assembly Core Bracket Trunion," Jurnal Ilmiah Teknik Industri, *10*(3), 245- 253, 2022.

[6] Brito, M. F., Ramos, A. L., Carneiro, P., & Gonçalves, M. A., "A continuous improvement assessment tool, considering lean, safety and ergonomics," International Journal of Lean Six Sigma, 11(5), 893–916, 2020.

[7] Kusuma, I. F., Hartanti, R. I., & Hasan, M., " Pengaruh posisi kerja terhadap kejadian low back pain pada pekerja di Kampung Sepatu, Kelurahan Miji, Kecamatan Prajurit Kulon, Kota Mojokerto," Jurnal Ilmu Kesehatan Masyarakat, *10*(1), 2014.

[8] Nurmutia, S., Ruspendi, Rusmalah, "Ergonomi Industri. Tanggerang Selatan," Unpam Press, 2022.

[9] Middlesworth, M., MS, ATC/L, CEES. "A Guide REBA: Rapid Entire Body Assessment". http://ergoplus.com/wp-content/uploads/REBA-A-Step-by-Step-Guide.pdf.

[10] Yassierli, Yassierli, Dwina Oktoviona, and Inayati Ulin Naâ., "Hubungan antara Indikator Pengukuran Kelelahan Kerja dan Metode Cepat Penilaian Risiko Ergonomi," Ergonomi dan K3 1.1, 2016.

[11] Afriza, F., Dipoatmodjo, T. S., & Ruma, Z., "Pengaruh Kompetensi Karyawan Terhadap Kinerja pada PT. Bank Negara Indonesia (Persero) Tbk. Kantor Cabang Bulukumba," Southeast Asia Journal of Business, Accounting, and Entrepreneurship, *2*(2), 8-16, 2024.

[12] Usmadi, U., "Pengujian Persyaratan Analisis (Uji Homogenitas Dan Uji Normalitas). Inovasi Pendidikan," 7(1), 50–62, 2020, https://doi.org/10.31869/ip.v7i1.2281.

[13] Astrand, P., & Rodahl, K., "Textbook of work physiology: Physiological based of exercise," McGraw Hill, New York, 1986.

[14] Artayasa, I. N., "Ergonomic Stairs Reduces Fatigue of Coconut Transporter Women in Bali," American Journal of Engineering and Technology Management 2021, 6(6), 117-125, 2021.

[15] Akbar, M., "The Infuence of Leadership and Work Environment on Employee Performance: A Case Study of Private University in Jakarta," European Journal of Research and Reflection in Educational Sciences, 5(1), 85–95, 2017.

[16] Yohanes, R., Al-Muqaffa, F. W., Kusnadi, “Analisis Postur Kerja Menggunakan Metode REBA dan Kuesioner NBM Pada Operator Mesin Sizing SA-80 N1 di Industri Otomotif,” *INDUSTRIKA*. E-ISSN: 2579-5732. P. 164-174, 2025.
[17] Salsabila, N. R. N., “Perbaikan Sistem Kerja Menggunakan Pendekatan Lean Ergonomic Pada Proses Leveling Damper (Studi Kasus di PT. Yamaha Indonesia)”. 2018.
[18] Noor, S. N. A. M., Ahmad, I. N., Wahab, N. A., Ma’arof, M. I. N., “Review of Studies Concerning Prolonged Standing Working Posture,” Advanced Engineering Forum. Published by Trans Tech Publications Ltd, Switzerland. ISSN: 2234-991X, Vol. 10, pp 131-136, 2018, doi:104028/ www.scientific.net/EF.10.131.
[19] Anggrianti, S. M., Kurniawan, B., & Widjasena, B., “Hubungan antara postur kerja berdiri dengan keluhan nyeri kaki pada pekerja aktivitas mekanik section welding di PT. X.,” Jurnal Kesehatan Masyarakat, *5*(5), 369-377, 2017.
[20] Seravalle, G., & Grassi, G., “Heart rate as cardiovascular risk factor,” In Postgraduate Medicine (Vol. 132, Issue 4, pp. 358–367), 2017, Taylor and Francis Inc. https://doi.org/10.1080/00325481.2020.1738142