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Improvement of working posture in the metal casting industry to prevent musculoskeletal disorders

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ABSTRACT

Less ergonomic work postures such as bending and squatting have the potential to pose work risks. When muscles receive static loads repeatedly and for a long time, it causes complaints of damage to joints, ligaments, and tendons commonly referred to as musculoskeletal disorders (MSDs) or injuries to the musculoskeletal system. This study aimed to determine the level of risk of work postures performed by workers in each work activity using the Rapid Entire Body Assessment (REBA) and Ovako Working Posture Analysis System (OWAS) methods and provide suggestions for improving work postures to minimise the occurrence of work risks. The research was conducted at the foundry of metal in the Casting section. Initial data in the form of Nordic Body Map (NBM) questionnaire data used to determine complaints in the musculoskeletal system and data in the form of image documentation on each work activity used as material for analysing the assessment of the REBA and OWAS methods. Proposals for improving the working posture were given in the form of adding foundations for moulding and pattern-making activities, the design of tools for metal liquid pouring activities, and furnace designs for metal smelting. Proposals for improving the working posture were given in the form of adding foundations for moulding and pattern making, the design of tools for metal liquid pouring, and furnace designs for metal smelting.

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1. Introduction

The rapid development of industry led to a reduction in the use of human labour which then resulted in a shift from humans to machines [1]. However, humans play an important role in manual material handling (MMH). Manual material handling is the manual transfer of material that relies heavily on the human body for operators to perform lifting operations in a limited space. In fact, non-ergonomic MMH is one of the factors that cause work accidents. This is also known as over-exertion lifting and carrying that damage to body tissues. For instance, it is caused by excessive lifting of luggage [2]. One or more personnel engage in MMH, which entails lifting, disembarking, pushing, pulling, transporting, and moving objects [3]. The definition of MMH as it stands currently only encompasses lifting and lowering exercises that consider various components of vertical strength [4]. There are still pushing and pulling actions in MMH activities even though they are not just the aforementioned tasks. MMH activities that are often carried out by workers in the industry include lifting tasks, carrying tasks, pushing tasks, and pulling tasks [5]–[7].

Businessmen in the manufacturing industry certainly expect continuous production. This is done to achieve the set production goals. With this expectation, machines, and manpower will have to work long

hours. Machines can operate for a long time because they do not experience fatigue like humans do. In order to protect workers from harm, optimum work practices and ergonomic workspaces must accommodate the utilization of lengthy human working hours [8].

Musculoskeletal issues range from very minor to extremely painful complaints that a person experiences in their skeletal muscles [9], [10]. The muscle may have symptoms in the form of damage to joints, ligaments, and tendons if static loads are applied to it frequently and over an extended period of time. Musculoskeletal disorders (MSDs) or injuries to the musculoskeletal system are the most common terms used to describe complaints of injury [11]–[13]. According to biology, the development of musculoskeletal problems is triggered by the delivery of an excessively demanding workload with a protracted load duration that results in maximum muscular contractions that surpass 20%. Because of this, blood flow to muscles decreases in proportion to the strength of contraction; lower blood flow also reduces oxygen delivery to muscles, which inhibits carbohydrate metabolism and leads to lactic acid buildup that produces muscle soreness [14], [15].

CV. Putra Sari Logam is a company engaged in manufacturing metal casting. The products produced are various models of lampposts, garden chairs, and so on. In meeting such high market demand, it caused 6 workers on the production floor, especially in the Casting section with mould-making activities, metal smelting, pouring metal liquid, and who took the pattern/product to be overwhelmed and had to work overtime up to 2-3 times for one week. The average overtime starting from 16.00-21.00 can even reach 02.00 depending on the conditional target to be produced. Often, CV. Putra Sari Logam pays/hires piece workers so that product demand can match the predetermined production targets. This production activity was carried out every day from 08.00-16.00 with a break from 11.30-13.00. In addition, workers must work in a hot environment which is one of the factors that cause MSDs complaints. Factors causing musculoskeletal disorders other than the work climate include work postures that are less ergonomic and done repeatedly such as backs that are too bent, knees that are too bent and coupled with psychosocial pressure that exists in the workplace targeted by workplace leaders affect work stress [15], [16].

Based on the observations, researchers used the Nordic Body Map (NBM) questionnaire to determine the complaints of MSDs felt by workers. Of 6 workers on the production floor, 5 workers were found to have pain in the left and right shoulders, 4 workers experienced pain in the waist and back, 3 workers experienced pain in the neck and upper left and right arms and 2 people experienced pain in the calves and ankles. This problem would have an impact on workers and also on company management or business owners, namely there can be a decrease in work productivity on the production floor of CV. Putra Sari Logam.

Ergonomic posture assessment can be done using the Rapid Entire Body Assessment (REBA) method and the Ovako Working Posture Analysis System (OWAS) method [17], [18]. Bending and squatting work postures are less ergonomic and have the potential to cause occupational risks. The REBA method allows a joint analysis of the position that occurs in the upper limbs (upper arms, forearms, and wrists), body, neck, and legs. This method also defines other factors such as the type of handle or the type of muscle activity carried out by the worker [19]–[21]. The OWAS method is a method that evaluates and analyzes uncomfortable work attitudes that result in musculoskeletal injuries. The observed work attitude section includes the movement of body parts from the back, shoulders, hands, and feet [22], [23]. The OWAS method is very appropriate to be applied to the company's production analysis because there are company production activities that do not meet the level of comfort for these workers. In this company, no one has ever researched the analysis of workers' postures. The use of two methods in this study was carried out to compare and determine the level of risk of the two methods on the work on the production floor of CV. Putra Sari Logam. So, that it could be concluded later whether a recommendation for improvement will be made or not. Researchers were interested in

conducting research on the analysis of workers' postures in CV. Putra Sari Logam uses REBA and OWAS methods.

2. Method

The data collection technique in this research used a qualitative approach with a saturated sample method. This technique is used if the number of populations is small, namely less or equal to 30 respondents or the number of populations is limited [24]. Thus, the sum of the entire population is sampled for the study. The population in this study was 6 people who were all workers on the production floor of CV. Putra Sari Logam.

The method used in retrieving data was obtained by taking measurements directly on workers using NBM questionnaires, in-depth observations, and interviews with workers as well as REBA and OWAS calculations. The use of the method in this study aimed to determine the level of risk and application of ergonomics to workers so that it could provide solutions to CV. Putra Sari Logam in overcoming the risk of injury to these workers.

This primary data was obtained from observations, namely by providing a Nordic Body Map questionnaire which then the workers on the CV. Putra Sari Logam, especially in the production department, was interviewed to fill out the Nordic Body Map questionnaire. This observation was also done by documenting pictures or videos of manual material handling work activities directly on the object of research. So, the researchers would easily find out the technique of manual material handling activities carried out by workers and whether they were in accordance with ergonomic aspects and how much the level of ergonomic risk was carried out by workers. This finding could enrich the analysis and answer this research problem. The activities that were the object of research include the following:

a. Mould making
   Mould making is the initial stage in metal casting work. In this activity, workers make moulds with sand according to the pattern or design of the product to be produced.
b. Smelting metals
   Workers melt materials/metals into the smelting furnace and wait for the metal to become liquid until it is ready to be picked up by workers who will pour the metal liquid into the mould.
c. Pouring metal liquid
   This activity is to take the metal liquid from the furnace using the tools commonly used by workers, then workers pour the metal liquid into the mould that has been made before.
d. Taking the product
   This activity is carried out by workers to take hardened products from inside the mould. This activity is assisted by using a tool in the form of an iron hook.

Secondary data is data used to support this research, namely in the form of documents such as journals, books about ergonomics, musculoskeletal disorders, and so on. NBM is used to determine the complaints of MSDs felt by workers. These MSDs complaints will be known using a questionnaire in the form of several types of MSDs complaints on the human body map. NBM is intended to find out more details about body parts that experience disturbances or pain while working [25]. Respondents who filled out the questionnaire were asked to provide signs of the presence or absence of disturbances in that part of the body area. Through this questionnaire, it can be known the part of the muscle that experiences complaints with the level of complaints ranging from Not Hurting, Somewhat Painful, Sick, and Very Sick. NBM results can estimate the type and extent of complaints, fatigue, and pain in the parts of the muscles that workers feel, by looking at and analyzing body maps taken from filling out NBM questionnaires ranging from discomfort to extreme pain.

Rapid Entire Body Assessment is a method developed in the field of ergonomics that quickly assesses the position or working posture of the operator's neck, back, arms, wrists, and feet [26], [27]. Evaluating by using REBA does not take much time to complete a list of activities and make a general assessment of the need for risk reduction due to the operator's work attitude [21], [28]. The followings are the steps in the application of the REBA method and the assessment sheet in Fig. 1.

a. REBA is divided into two groups, namely Group A and Group B, where Group A consists of the body, neck, and legs while Group B consists of the upper limbs (upper arms, forearms, and wrists). Groups A and B are then calculated to get each individual's score.
b. Group A scores are obtained from calculations on the body, neck, and legs.
c. Group B scores are obtained from calculations on the upper body (upper arms, forearms, and wrists).
d. The value of the A score obtained from the Group A score is carried out by the modification of the score in Table A depending on the load lifted on the worker.
e. The value of the B score obtained from the group B score is modified to the score in Table B depending on the type of handle on the worker when holding the object to be moved, which is then called the B score.
f. Then after obtaining the A and B scores proceed to look for the C scores obtained in Table C.
g. From the calculation results of the C score, check the risk level, risk category, and corrective actions that must be taken.

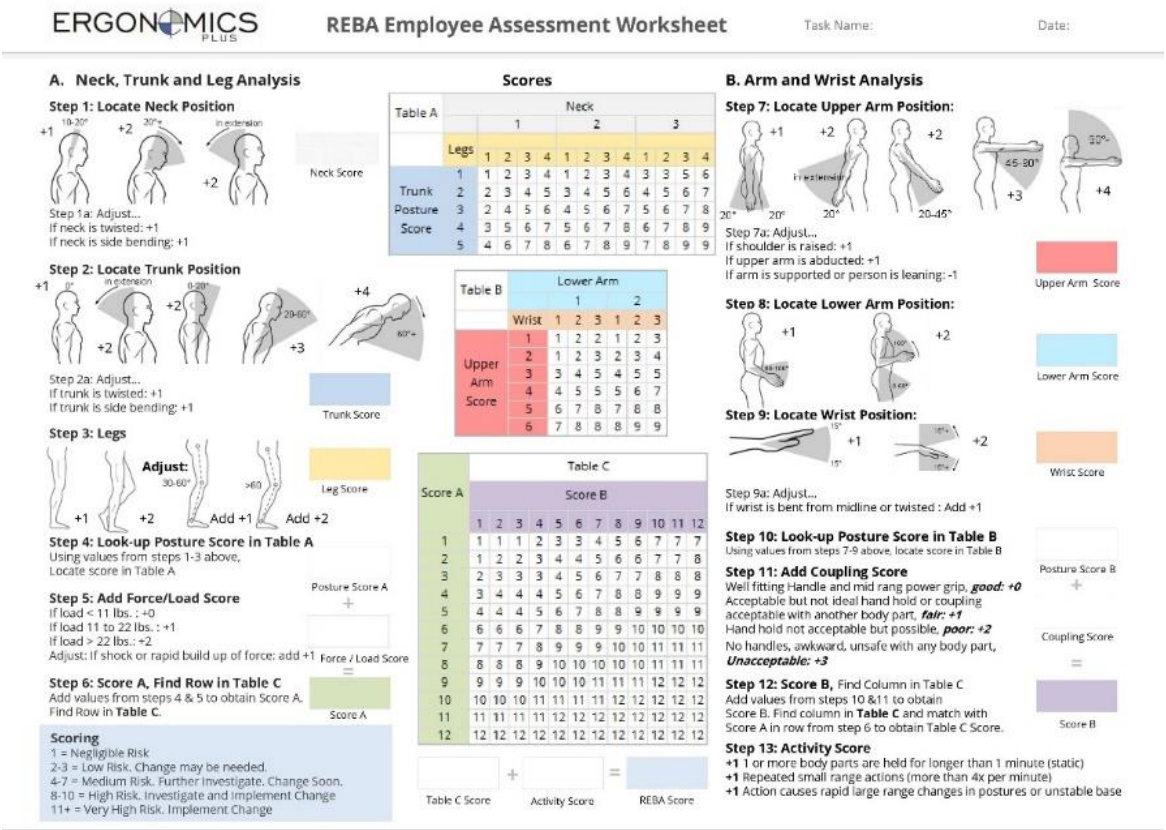


Fig. 1. REBA Worksheet
Source: [21]

OWAS is a work attitude analysis method that defines the movement of the body parts of the back, arms, legs, and heavy weights lifted [22]. Each of those limbs is classified into work attitudes. The results of the OWAS work attitude analysis consist of four levels of work attitude scales that are harmful to workers [29].

Category 1: This attitude does not matter in the musculoskeletal system. No need for improvement. Category 2: This attitude is slightly harmful to the musculoskeletal system (work attitudes result in a significant influence of tension). It needs improvement in the future. Category 3: This attitude is harmful to the musculoskeletal system (work attitudes result in a very significant influence of tension). Needs immediate improvement possible. Category 4: This attitude is very harmful to the musculoskeletal system (this work attitude results in obvious risks). Needs direct/current improvement.

The OWAS worksheet is divided into four main parts that are analyzed namely the body parts of the back, arms, legs, and heavy weights that are lifted. Each of those limbs is classified into work attitudes. The following is a classification of the attitudes of the observed body parts to be analysed and evaluated.

a. In analysing the OWAS worksheet, the first step is to classify the back, and then determine the back position from the number the worker is performing.
b. Then classify the arm positions of the workers, and determine which arm position is in which number in the classification order.
c. After that classify the footstrike in each worker. This step has the same way as the first and second steps.
d. The next step is to find out how much weight is lifted by the worker. After getting the weight, then calculate the OWAS score.
e. From the results of the OWAS score, four levels of the work attitude scale can then be determined whether it is dangerous or not for workers.

In addition to NBM, REBA, and OWAS worksheets, other necessary tools are a protractor and camera/smartphone. A protractor is used to calculate the angle of position of body parts to facilitate calculations in REBA worksheets and OWAS worksheets. Camera/Smartphone is used to take documentation in the form of pictures of workers who are doing work. Taking pictures or photos is useful to help in analysing the posture of workers in doing manual material handling work.

The last stage, namely data analysis techniques using the Miles and Huberman model, has three steps including data reduction, data presentation, and conclusion drawing [30].

a. Data reduction is carried out by selecting and summarizing important data and getting a clear picture after data reduction. The data used in this study is in the form of data from the NBM questionnaire, pictures, or videos when workers do their work.
b. Data presentation in the form of a brief explanation so that the research data is easier to understand. In addition, it can be graphs, charts, and tables as well as descriptive.
c. Conclusion drawing, if the conclusion contains valid evidence, then the conclusion is credible. Drawing this conclusion will determine whether the study is useful or not.

3. Results and Discussion

The data in this study is in the form of worker activity data in the Casting section on metal melting, mould making, pouring metal liquid, and taking patterns/products at CV. Putra Sari Logam. The main data is related to the work posture carried out by workers and then documentation was carried out in the form of images/videos for each work activity. Furthermore, the identification of angle measurements was carried out using the Corel Draw software. This angle measurement is related to the risk level assessment in the REBA method, while for the OWAS method, the risk level assessment is only seen from the

movement of work postures performed by workers [27], [31]. Another data need is that the NBM is carried out by observation, direct interviews with workers, and filling out questionnaires for respondents in each work activity studied. This NBM data is only used to identify whether the activities carried out by the worker have musculoskeletal complaints or not.

3.1. Analysis of MSDs Complaints Based on NBM Questionnaire

Analysis of Musculoskeletal Disorders complaints in workers, namely by using the NBM questionnaire, aims to make it easier for researchers to find out the complaints that workers feel while doing their work. The NBM questionnaire contains the type of complaint as well as the level of complaint felt by the worker. The level of complaints felt by workers is divided into four categories, namely a score of 1 for the Not Sick (NS) category, a score of 2 for Somewhat Sick (SS), a score of 3 for Sick (S), and a Score of 4 Very Sick (VS). This analysis was carried out on 6 workers on the production floor of CV. Putra Sari Logam. The results of the NBM questionnaire can be seen in Table 1.

Table 1. Recapitulation of NBM Questionnaire Total Score

No	Types of Complaints	Complaint Rate			
		NS (1)	SS (2)	S (3)	VS (4)
0	Pain in the upper neck	3	1	2	0
1	Pain under the neck	3		3	
2	Pain in the left shoulder	1		5	
3	Pain in the right shoulder	1		5	
4	Pain in the upper left of the arm	3		3	
5	Back pain	1	2	2	1
6	Pain in the upper right of the arm	3		3	
7	Lumbar pain		4	1	1
8	Pain in the buttocks	6			
9	Pain in the lower part of the buttocks	6			
10	Pain in the left elbow	5	1		
11	Pain in the right elbow	5	1		
12	Pain in the left forearm	4	1	1	
13	Pain in the right forearm	4	1	1	
14	Pain in the left wrist	6			
15	Pain in the right wrist	6			
16	Pain in the left hand	4	2		
17	Pain in the right hand	4	2		
18	Pain in the left thigh	6			
19	Pain in the right thigh	6			
20	Pain in the left knee	6			
21	Pain in the right knee	6			
22	Pain in the left calf	4	1	1	
23	Pain in the right calf	4	1	1	
24	Pain in the left ankle	4		2	
25	Pain in the right ankle	4		2	
26	Pain in the left leg	3	2	1	
27	Pain in the right leg	3	2	1	
	Total Score	111	42	102	8
	Average		65.75		

Based on the results of Table 1, an average total score of 65.75 shows that the level of complaints is in the moderate category which may require future action. The NMB complaint rate scale can be seen in Table 2. It is also known that complaints in the form of pain with the risk of injury experienced by the average worker are found in the neck, shoulders, back, waist, upper left, and right arms left and right legs. This pain can occur due to activities carried out by workers repeatedly with a less ergonomic work posture.

Table 2. Risk Level Classification NMB Score Calculation [31], [32]

No	Total Score	Risk Level	Remedial Action
1	28-49	Low	No corrective action is needed yet
2	50-70	Keep	Action may be needed in the future
3	71-90	High	Immediate action required
4	92-122	Very High	Thorough action is required as soon as possible

3.2. Work Posture Analysis Using REBA and OWAS

Assessment of work attitudes on the production floor of the CV. Putra Sari Logam was carried out in the activities of making moulds, smelting metal on furnaces, pouring metal liquids, and taking patterns/products.

Table 3. Work Activity

Work Activity	Work Activity Images
Mould Making	
Metal Smelting	
Pouring of Metal Liquids	
Product Pickup	

This work attitude assessment was carried out starting with data collection in the form of pictures or videos using a camera/smartphone. Table 3 is the result of the analysis of working posture images using the REBA and OWAS methods.

3.3. Recapitulation of REBA and OWAS Method Analysis Results

Data processing on body posture produced a variety of results. Data processing using the REBA and OWAS methods has stages that are in accordance with each method used. The recapitulation of the results based on data processing can be seen in Tables 4 and Table 5.

Table 4. Recapitulation of the REBA Method

No	Work Activity	REBA			
		Score	Risk Level	Category	Repair
1	Mould Making	8	3	High	Immediate action required
2	Metal Smelting	9	3	High	Immediate action required
3	Pouring of Metal Liquids	10	3	High	Immediate action required
4	Product Pickup	4	2	Keep	Action may be required

As presented in Table 4, the four work activities have a moderate and high-risk categories. For work activities with a high category, namely in making moulds with a score of 8, metal smelting gets a value of 9, and pouring metal liquids gets a value of 10 means that immediate action is needed on the activity. While work activities that are categorized as moderate risk are product collection activities with a REBA score of 4 means that the risk category may require corrective action. The high-risk category occurs because there are influencing factors in the REBA score calculation analysis such as a back that is too bent, legs that bend too much, and a neck that is too high. So, it can be concluded that these activities are less ergonomic and need to be improved posture to minimize the occurrence of work risks.

Table 5. Recapitulation of OWAS Method

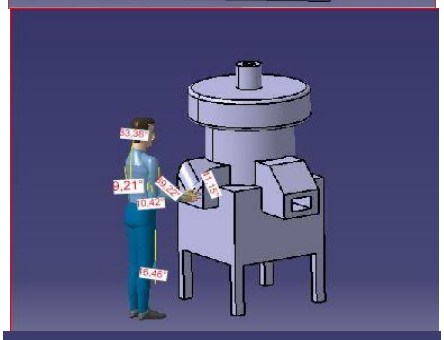
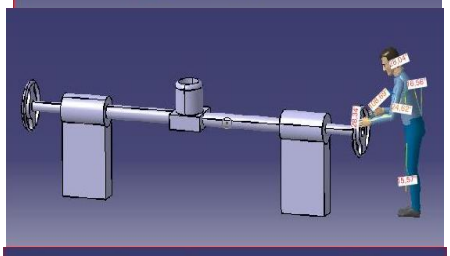
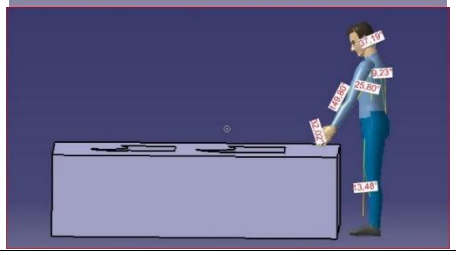
No	Work Activity	OWAS		
		Score	Category	Repair
1	Mould Making	2	Keep	Action required
2	Metal Smelting	3	High	Immediate action required
3	Pouring Metal Liquids	3	High	Immediate action required
4	Product Pickup	3	High	Immediate action required

According to Table 5, the four work activities have a moderate and high-risk category, which means that the risk category requires corrective action. Work activities that are categorized as moderate are in the manufacture of moulds, while work activities that are categorized as high in risk are in metal smelting, pouring metal liquids, and taking products. The high-risk category occurs because the value of each OWAS work attitude classification has a high value. The classification of work attitudes includes attitudes on the back, legs, and arms and the weight of the load lifted by workers also affects the calculation of the OWAS score value. An OWAS score of 2 means on this attitude is dangerous in the musculoskeletal system so it needs improvement in the future. An OWAS score of 3 means that this attitude is harmful to the musculoskeletal system (the work attitude results in a very significant influence of tension) and needs immediate improvement.

3.4. Proposed Remedial Actions

This proposed corrective action is in the form of a work floor design by considering human, material, and machine factors. Proposed corrective actions are carried out to eliminate or minimize the level of score assessment based on the needs of workers in carrying out their work and for the prevention of occupational risks or work accidents. Table 6 is the recommended work activities from the risk score assessment analysis for the above workers.

Table 6. Proposed Improvement of Every Work Activity

Work Activity	Proposed Improvements	Tool Design Image
Mould Making	Foundation Additions	
Metal Smelting	Smelting Furnace Design	
Pouring of Metal Liquids	Pouring Aids	
Product Pickup	Foundation Additions	

Furthermore, an analysis was carried out using the REBA and OWAS methods on the working posture after improvements were made. The results of the calculation analysis can be seen in Table 7.

Table 7. Recapitulation of REBA Method Proposed Improvements

No	Work Activity	REBA			
		Score	Risk Level	Category	Repair
1	Mould Making	3	1	Low	Action may be required
2	Metal Smelting	3	1	Low	Action may be required
3	Pouring of Metal Liquids	4	2	Keep	Further investigation, for corrective action
4	Product Pickup	3	1	Low	Action may be required

As shown in Table 7, the four work activities after the proposed improvements have low and moderate risk categories which means that further corrective and investigative action may be needed. Corrective actions need to be implemented in all four activities of the casting section. Work activities that are categorized as low, namely in the manufacture of moulds, metal smelting, and product retrieval, while work activities that are categorized as a medium are in the pouring of metal liquids. It can be concluded that after the proposed improvements there is a decrease in the score of each work activity.

Table 8. Recapitulation of OWAS Method Proposed Improvements

No	Work Activity	OWAS		
		Score	Risk	Information
1	Mould Making	2	A little dangerous	Needs improvement in the future
2	Metal Smelting	1	No problem	No need for improvement
3	Pouring Metal Liquids	2	A little dangerous	Needs improvement in the future
4	Product Pickup	1	No problem	No need for improvement

According to Table 8, work activities have a score of 1 for metal smelting and product retrieval activities. A score of 1 means that attitude does not matter in the musculoskeletal system. For mould-making activities and pouring metal liquids getting an OWAS score of 2 means that the attitude is slightly harmful to the musculoskeletal system so improvement is needed in the future. Thus, it can be concluded that the OWAS score decreased after the proposed improvement was carried out.

4. Conclusion

Based on the results of data processing, analysis, and provision of improvement proposals in this study, it is concluded that the assessment of work activity posture using the NBM method obtained an average total score of 65.75 which indicates that the level of complaints is in the moderate category which may need future action. Complaints experienced by the average worker in the form of pain were found in the neck, shoulders, back, waist, upper left, and right arms left and right legs. A score of 8–10 with a high category/dangerous for musculoskeletal was achieved based on the analysis utilizing the REBA method on the creation of moulds, melting of metal, and pouring of metal liquids; hence, immediate action is required. For product collection activities, a REBA score of 4 with a moderate risk category is obtained, which means that corrective action may be needed for the activity.

Using the OWAS method, an OWAS score of 3 was obtained for activities that have a dangerous risk level, namely metal smelting activities, pouring metal liquids, and taking products so immediate corrective action needs to be taken. A REBA score of 2, which indicates a slightly serious risk category, was found for the product moulding manufacturing activities, indicating that future improvements are required.

Proposed improvements to reduce musculoskeletal injuries or complaints are by providing tools in the form of additional foundations for mould-making and pattern-making activities, designing tools for metal liquid pouring activities, and designing furnaces for metal smelting. According to the study of the suggested improvements, utilizing the REBA and OWAS methods resulted in a lower value for the risk level and risk category.

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