Work postural analysis and musculoskeletal injury risk in critical working station at XYZ Ceramics Yogyakarta

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Abstract. Companies that have manual work, muscle injury is one of the major health issues that often occur when working. XYZ Ceramics Yogyakarta is still doing work activities involving manual processes and there has been identified that worker posture has the potential to cause injury. From the Nordic Body Map questionnaire, complaint was identified in the back were 88%, the knees were 80%, the upper arm 75%, and the right *shoulder* by 70% from 15 workers. The Ovako Work Posture Analysis System (OWAS) method is used to evaluate and analyze work attitudes so that improved categories of work methods and recommendations could be obtained. Plan for *Identifiering av Belastningsfaktorer* (PLIBEL) was used to identify the factors that cause muscle injury or harmful effect. In addition, the Nordic Body Map was applied to determine the critical work station. The purpose of this research is to analyze work posture and description of risk level related to musculoskeletal injury at critical work station. The three highest percentage of risk of muscle injury identified at raw material processing station, based on calculation result of PLIBEL Checklist, were on elbow, forearm, and hand. Based on the assessment of working posture using OWAS, the highest action category is identified in the activity of moving the cart containing the soil to the automatic pest that is the action category of 4, which means that this activity is very dangerous for the musculoskeletal system.

1 Introduction

In the industry, working in non-ergonomics conditions is definitely not comfortable and easy to get fatigue, which ultimately decreases productivity. The impact of this non-ergonomics condition is a musculoskeletal complaint. Musculoskeletal complaint is a complaint on the part of the skeletal muscles felt by someone, varied from very mild to very painful [1]. Musculoskeletal system allows humans to stand up and move. In addition, the muscular and skeletal system also serves to protect the vital organs in the body. Muscular and skeletal system is closely related to limb, every injury or interference with this system would lead to disruption of the movement of a person whether temporarily or permanently.

In Yogyakarta, precisely in Kasongan located in Banguntapan, Kasihan, Bantul, 95% of its citizens living as a potter. There are 408 business units with the number of workers over 2,000 people and has entered the commercial export market in the industrial district Kasongan [2]. In the printing process in ceramics pottery observed, the posture of operator's body did not comply with the ergonomics rules. The position of the lower rotary tool makes workers should bend their body during the manufacturing process, lift, and put the pottery. From Nordic Body Map questionnaires provided for the workers in the XYZ Ceramics show complaints of 68% in most of the body felt by the operator at the work station processing for raw materials, complaints by 64% on the portion of the body for operator at the workstation of formation, complaints by 59% in some body parts of the operator's in burning work stations, complaints by 60% in most part of the body in finishing workstations, and complaints by 61% from packing workstation. Thus, indicating that the work activities in the XYZ Ceramics cause discomfort on the musculoskeletal.

Some study that support this research was varied, listed two major contributions for this research. The first was using Quick Exposure Checklist (QEC), NIOSH, and RULA that designing a proper seating for Transformer manufacturing industry in Germany on workers at coil winding machine workstation [3]. In addition, the result suggested that the analysis and implementation of ergonomic chairs could provide a major difference that can minimize the pain of the operator's body. Move on to the second research, which performed an assessment of operator posture in steel pipe production using OWAS, concluded that to develop a system of rotation of employees at workstations and ergonomic changes at the same time implementing preventive programs [4]. Both researches could emphasized on the need of using postural analysis to describe the occupational condition of a workstation and provide better solutions to improve the productivity. Moreover, this research also strengthened by

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the use of PLIBEL (Plan for Identifering avbelastnings faktorer) to identify root cause of injury [5]. Therefore, this research was needed to be conducted in five stages. The determination of critical workstation was the first stage to identify the workstation that has the highest risk of musculoskeletal injury. There were 15 operators of XYZ Ceramics that fulfilling the questionnaire of Nordic body map. After the identification of the root causes of muscle injury that can cause harmful effects by using PLIBEL. Then, this research performed the assessment work posture or attitude using OWAS to evaluate and analyze the work attitude uncomfortable and result in injury musculoskeletal [1]. After the result of the identification of the risk factors of injury by using PLIBEL and posture assessment using OWAS were used to make suggestions or recommendations for work improvement. Moreover, these recommendations should be limited to create working conditions that are effective, convenient, safe, efficient, and also minimize the risk of injury to the operator who perform the work.

Objects in this study was the small businesses that addresses XYZ Ceramics in Kasongan Bantul, Yogyakarta. The samples taken which covered in the criteria for inclusion were 15 workers in the XYZ Ceramics Yogyakarta, which are respectively 3 work stations processing of raw materials, forming, firing, finishing and packing. Collecting data in this study were preliminary observations in the form of evaluation of the potential and symptoms of musculoskeletal complaints using Nordic Body Map questionnaires and PLIBEL checklist to identify the cause of the risk of injury.

2 Results and Discussions

This research was described on three main results based on the method used and continued with the future recommendations to ensure the improvement were made.

2.1 Musculoskeletal Complaint Analysis using Nordic Body Map Questionnaire

Nordic body map questionnaire describing the nuisance or complaints (pain, tenderness and stiffness) in the body during work performed. Using this questionnaire will impose the parts of muscle that have complaints with the various level of symptoms, ranging from discomfort (not ill) until severely ill (very ill) [6]. There were five work stations in the production at the XYZ Ceramics, namely raw material processing, forming, firing, finishing and packing. Raw material processing work station consisted of three operators, three operators at the work station formation, three operators on combustion, three operators on finishing, and three operators on the packing. The data resulted from the questionnaire from Nordic Body Map of an operator on raw material workstation can be seen in Table 1.

The weighting rate of Nordic Body Map questionnaire are categorized as follows:

1) Weights for no pain (discomfort/not ill) scale is 1,
2) The weights for the scale a bit sore (mildly ill) is 2,
3) Weights for pain (ill) scale is 3, and
4) Weights for scales of very sick (severely ill/very ill) was 4.

Furthermore, then calculate the score of each skeletal muscle complaints, the following is an example of how the calculation processed:

Sore / stiff in the upper neck = the total number of weights = total x weights

= (0 x 1) + (0 x 2) + (1 x 3) + (0 x 4) = 3

After the scores from each section of musculoskeletal has been obtained, then calculate the overall in total. To demonstrate clear the level of risk in each part of the body, it is provided marks with different colors according to the following conditions: the color blue is used to lower the risk level with a range of score 28 to 49, the color green is used to level the risk of being with a range of scores from 50 to 70, the yellow color is used for high-risk level with a range score of 71 up to 91, while red is used for the level of risk is very high with a range of scores 92 to the 112.

The results of the overall total score of each workstation operator is described on Table 2. The total score obtained indicate the level of risk of injury on the job every workstation observed. From the results of the questionnaire calculation of Nordic Body Map at each workstation that is part of the production can be seen that there are critical work stations at the workstation for processing of raw materials. Especially in the third operator processing of raw materials workstation that obtained results that indicate a high risk level.

Table 1. Nordic body map questionnaire for operator 1 in raw material workstation

Complaint Type	Discomfort/ Not ill	Mildly ill	ill	Severely ill/ very ill	Score
Sick/ stiff in the upper neck	0	0	1	0	3
Hospitals / stiff in the lower neck	0	1	0	0	2
Pain in the left shoulder	0	1	0	0	2
Pain in right shoulder	0	0	0	1	4
Pain in the upper arm left	1	0	0	0	1
Pain in the back	0	0	0	1	4
Sick The upper arm right	0	0	1	0	3
Hospital at waist	0	1	0	0	2
Pain in the butt	0	0	1	0	3
Hospital dipantat	1	0	0	0	1
Pain in the left elbow	1	0	0	0	1
Pain in right elbow	0	1	0	0	2
pain in the left forearm	0	0	1	0	3
pain in the right forearm	0	0	1	0	3
pain in the left wrist	0	1	0	0	2
pain in the right wrist	0	0	1	0	3
pain in his left	0	0	0	1	4
ill The right hand	0	0	1	0	3
Pain in the left thigh	0	0	1	0	3
Pain in the right thigh	0	0	0	1	4
Pain in the left knee	0	0	1	0	3
Pain in the right knee	0	0	1	0	3
Pain in his left calf	0	0	1	0	3
Pain in right calf	0	0	1	0	3
Pain in the left ankle	0	1	0	0	2
Pain in the right ankle	0	1	0	0	2
Pain in the left leg	0	0	1	0	3
Hospital on the right foot	0	0	1	0	3
Total	3	7	14	4	75

From the calculation of questionnaire, the Nordic body map in raw material processing workstation, the operator first obtained results score of 75, the operator 2 by 75, and the operator 3 for 76. All three scores indicate

that level of risk of injury. musculoskeletal a high Additionally obtained complaints highest limb is on the right shoulder and back. Activities of workers when bent spine resulted in moves to the front side of the body, the muscles of the stomach and the front side of disc in the vertebratal in the lumbar suppressed. On the ligament back side of in vertebratal disk instead to stretch or sag [7]. This condition causes pain in the back. Besides the shoulder including a risky position if the position of the lift at the shoulders to form an angle of ≥ 450 from the vertical axis of the body, either laterally of the body and towards the front of the body [8].

Table 2. Summary of total score nordic body map

Work Station	Operator	Score	Risk Level
Processing of Raw Materials	Operator 1	75	High
	Operator 2	75	High
	Operator 3	76	
High-Formation	Operator 1	74	High
	Operator 2	73	high
	Operator 3	69	Average
Combustion	Operator 1	63	Average
	Operator 2	65	Average
	Operator 3	70	Average
Finishing	Operator 1	66	Average
	Operator 2	69	Average
	Operator 3	67	Average
Packing	Operator 1	71	high
	Operator 2	69	Medium
	Operator 3	66	Medium

2.2 Injury Risk Factors Analysis Using PLIBEL Checklist

Data processing PLIBEL checklist obtained by calculating the percentage value obtained from any member of the body. This percentage value obtained by counting the number of "yes" in each column PLIBEL checklist that has been filled, then dividing by the total number of questions in the answer and multiplied by 100%. The results of data processing PLIBEL checklist for the operators in raw material processing work station are presented next. The results of data processing showed that the percentage value of the risk of injury to the operator 1 at the work station processing of raw materials to the neck, shoulders and upper back are 62%, elbow, forearm and hand by 73%, leg by 38%, knees and hips by 38%, and for the lower back by 62%. As for the environmental score of 50%. The results showed that the value of the percentage of the risk of injury to the operator 2 at the work station processing of raw materials to the neck, shoulders and upper back are 58%, elbow, forearm and hand by 73%, the feet of 38%, knees and hips by 38%, and for the lower back by 57%. As for the environmental score of 50%. Moreover, the results showed that the value of the percentage of the risk of injury to the operator 3 at the work station processing of raw materials to the neck, shoulders and upper back are 58%, elbow, forearm and hand by 64%, foot by 38 %, knees and hips by 38%, and for the lower back by 57%. For more details, can be seen in the chart below, Figure 1.

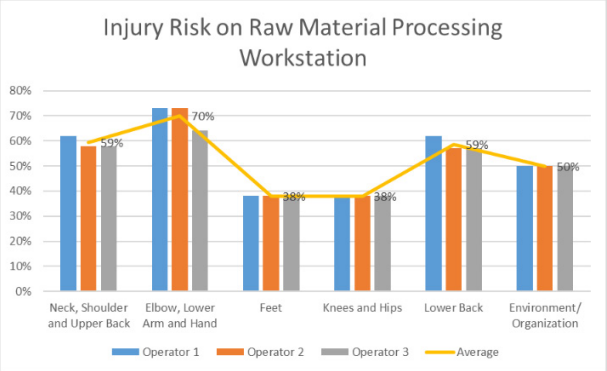

Fig 1. Injury risk on raw material processing workstation

The figure shows that the average on the body of the elbow, forearm and hand have a percentage of the highest risk of injury when compared with other body parts. Activities during the digging work resulted in the movement full extension where the elbow is driven repeatedly into top and bottom.

Several different result from other researches describing the highest score depends on the working environment, not only type of work. The calculation from PLIBEL checklist obtained at the installation workstation of granito shows that part of the neck, shoulders and upper back has the most severe musculoskeletal complaints compared to other body parts [9]. In other case, during research on the design of the critical workstations on the assembly at PT. Primarindo Asia Infrastructure Tbk., the data obtained from the calculation PLIBEL concluded that the percentage of the risk of injury at the buffing workstation, the highest score in the elbow, forearm and hand, that is equal to 72.73% [5].

Based on the analysis for the musculoskeletal risk factors, which was conducted by reviewing the 'yes' answer on the PLIBEL checklist data for every body parts, the risk factors were the inappropriate work facility design on the raw material processing workstation, including the height of the automatic pestle that exceed the height of operator's shoulder. In this case, the elbow, arm and hand should work a lot harder, prolong repetitive action, and physical workload (lifting heavy 22 kg weight load, transferring the dirt contented basket under the feet of operator into the automatic pounder). The object that has more than 12.5 kg in weight, raised above the shoulder, under the knees, or along the arms to more than 25 times per day could inducing the muscle fatigue, muscle damage, tendons and surrounding tissues [10]. Moreover, unnatural grip on the basket resulting uncomfortable hand position. Lifting object using only the power of fingers is not allowed, because of the limited capability of finger muscle, that could lead to finger injury [11].

2.3 Working Posture Analysis Assessment OWAS

The first step is assessing the posture of workers to the critical work stations starting from the initial stage to the final stage of the process. Based on the result from the activity category, the operator working posture 1 on the processing of raw materials are as follow. The activities are hoeing raw materials, move the raw materials into the basket and lift the basket containing ground pounder to the automatic. The following are the steps in determining the categories of worker attitudes for phase 1 activities hoeing raw materials:

1. Code OWAS for phase 1 at the work station processing of raw materials is 2141, because of the attitude of the back shows the code OWAS 2, the attitude of the arms shows the code OWAS 1, attitude feet (legs) shows the code OWAS 4, and the weight of the load shows the code OWAS 1 (Table 3).
2. Stage column, enter the code back to the line of code attitude BACK with shading in figure 2. Still one line of code BACK, that has been shading then to the right side for shading in figure 2 ARMS code.
3. Stage on the line, put the foot attitude code to the line of code LEGS by shading in figure 4. Still one column at code LEGS that has been in shading, then shading towards the bottom for the number 1 on the LOAD line code.
4. Pull shading on columns LOAD and rows ARMS, so both traction intersect. Box Meeting this cross is the category/level work attitude, which in 2141 had OWAS code category/level 3, which means in this attitude harmful to the system musculoskeletal (working attitude has resulted in a very significant influence of tension) and in need of repair as soon as possible.

Table 2. Category rating OWAS in Phase Activity 1

BACK	ARMS	1			2			3			4			5			6			7			LEGS
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	LOAD
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2	
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	4	2	3	3	
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4	
3	1	1	1	1	1	1	1	1	1	4	3	3	3	4	4	4	1	1	1	1	1	1	
	2	2	2	3	1	1	1	1	1	4	4	4	4	4	4	4	3	3	3	1	1	1	
	3	2	2	3	1	1	1	2	3	4	4	4	4	4	4	4	4	4	4	1	1	1	
4	1	2	3	3	2	2	3	2	2	4	4	4	4	4	4	4	4	4	4	2	3	4	
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	

Based on Table 3 the results of the activities of Phase 1 work attitude categorization, hoeing raw material value is 3, which means in this attitude harmful to the musculoskeletal system (work postures lead to a very significant influence of tension) and need immediate repair perhaps. Based on the summary of the three operators, it can be seen that the results of the categorization of the working posture at all three operators generate action categories of action Similarly. The three operators due to movement to work almost the same activity. The value of the highest category is on the activities of transferring the basket containing soil into the automatic pounder that is resulted on the action category 4, which shows that this attitude is very dangerous on the system. In addition, musculoskeletal work postures also lead to an obvious risk and in need of repair directly or current too.

Fig 2. Operator hoeing raw materials

Can be seen in Figure 2 that the working attitude at this third category is the attitude of on the foot stand, rests with both feet with your knees slightly bent. Similarly, research conducted by [12], work attitude in category 3 obtained has a foot position that rests on both legs bent. This foot position does not provide a stable body of work, so that the body easily slips workers. Working attitude in this category have a significant harmful effect on the musculoskeletal system, so that the necessary repairs had to be made as soon as possible.

Fig 3. The operator insert raw materials into a basket

Shown in Figure 3, the placement position of raw materials under the reach of the hand or foot is parallel to the worker, forced the workers to perform the process of moving raw materials by means of bending and standing leg stance with their knees bent. Moreover, working in a

squatting position, bending and kneeling is also a posture awkward, the attitude or position of the body parts that deviate from the neutral position, significant deviation to the normal position will increase the workload of the muscle so that the amount of force needed is greater. This is because the result of the transfer of power from muscle to the skeletal system that are not efficient [10]. Therefore, this position needs improvement as soon as possible to avoid accidents and reduce musculoskeletal complaints seriously.

Fig 4. Operator entering raw material into automatic pounder

Based on Figure 4, the work attitude is very influential on the back. Heavy load and in the upper body (arms, shoulders, and upper back) resulted in a big moment in the spine caused by the distance the load to the body and the load is lifted exceed 10 kg. This condition, if performed repeatedly will cause disturbances in the back and waist in the form of musculoskeletal complaints [12]. Therefore, try to back and hip attitude cultivated in line when doing lifting activity. Because of these conditions can cause loading on the spine is relatively small, because the moment the body weight in the back does not happen.

2.4 Proposed Product

Based on the results of the above analysis, in order to minimize muscle injury in the XYZ Ceramics Yogyakarta operator is required to facilitate workers' tools while performing the job. In hence, the proposed products supplied in the form of a footrest to assist the operator when inserting the raw material into the automatic pounder and is expected to minimize the risk of muscle injury, especially on the neck, shoulders and arms. In designing this product proposal needed anthropometric data, size and determination percentile values are used to create a foothold in accordance with the rules of ergonomics. The dimensions of the body are taken into account are as follows: Standing shoulder height, Long and width of foot. Percentile used for the design of the footrests to be made is the fifth percentile that is 127.4 cm, then high pestle with a size of 138 cm automatically reduced by 127.4 cm so that the measures taken to footrest height is 10.6 cm. Meanwhile, the percentiles were used to draft a footrest to be made is the 95th percentile, which is 26.1 cm. Proposed footrest to be made used to assist or facilitate the operator when inserting the raw material into the automatic pounder for automatic grinding position is too high. The proposed design of the footrest can be seen in the figure below (Figure 5).

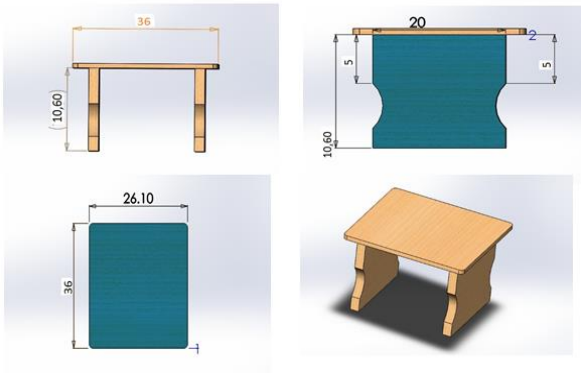

Fig 5. Proposed foot rest design

The measurement used for the design of the proposed design of the footrest obtained from percentile calculation for each section. Footrest height is 18.6 cm high, 5th percentile obtained from a shoulder stand, which is 127.4 cm, then high pestle with a size of 138 cm automatically reduced by 127.4 cm so that the measurement taken to footrest height is 10.6 cm. The length of 26.1 cm footrest is derived from the 95th percentile for the long dimension of the feet, while the width is 36 cm footrest length obtained from the position of the foot while standing parallel to the shoulders.

3 Conclusions

Based on the results of data processing and analysis has been done, the conclusions obtained are as follows:

a. a The factors that would cause musculoskeletal risk based on PLIBEL Checklist analysis are working facility design on processing of raw materials workstation, the physical load in the form of heavy lifting, and the not natural grips of the basket.
b. OWAS working posture assessment categories obtained, showed that the value of the highest action category is on the activities of transferring the basket containing ground into automatic pounder, which is on action category 4, that shows the very dangerous attitude on the musculoskeletal system and the need of direct improvement.
c. Recommendations given to improve the posture is a good working posture changes based on OWAS work attitude and add a footrest to assist the operator when inserting the raw material to automatic pounder

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