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WORK SAFETY ASPECTS USING A PARTICIPATORY ERGONOMIC APPROACH

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ABSTRACT
The problem that we often encounter in the workplace is work accidents. It is fatal in work and frequently ignored by workers and company owners, especially small and medium enterprises. This study focuses on reducing the risk of work accidents through a participatory ergonomic approach. This method is a method in which all elements involved in the scope of work are invited to work together to solve existing problems. The result shows that the risk of MSDs is dangerous to the musculoskeletal system as the work posture resulted in a significant effect of tension. The physical work environment is not under existing standards. Lack of lighting can be fatal to workers, while too hot temperatures can affect worker comfort. The results of participatory ergonomics show that 85% of workers want a change in the physical work environment. The number of work accidents in batik center after using a participatory ergonomic approach decreased and could increase work productivity by 11%.

INTRODUCTION

Ergonomics is a study that uses information about the nature of human capabilities and limitations in designing work systems. With ergonomics, it is expected that humans who play a central role in a working system can work more effectively and optimally (Sutalaksana et al., 2006). The awareness of ergonomics is necessary for developing countries, such as Indonesia. In general, the manufacturing sector consists of six main components: workplace, tasks, environment, management, as well as human and equipment operators (Mustafa et al., 2009). Developing countries heavily depend on small and medium enterprises (SMEs). However, MSD problems commonly appear among SME workers. Most SMEs do not realize the importance of ergonomics and are reluctant to adopt an ergonomic work environment. As a result, many workers ignore small problems that lead to fatal consequences called work-related musculoskeletal disorders (WMSD). WMSD is a disorder that occurs due to structural damage to the tendons, muscles, bones and joints, nerves, and blood vessel systems caused by the high-intensity repetitive work and lack of resting time (Simoneau et al., 2003). WMSD is

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significantly the main cause of industrial injury in both developed and developing countries (Knutsen et al., 2015).

One of the working process that was assessed in this field is the batik making process. Batik is a work of art originating from Indonesia that has many styles and uniqueness in each region. Batik Gedog Tuban is a typical batik of Tuban city. The center of Batik Gedog Tuban is located in Jarorero Village, RT 01 RW 01, Kerek District, Tuban Regency. Batik Center is the largest producer of Batik Gedog in Tuban city that produces various types of Tuban's typical batik products. The majority of Gedog hand-written batik is produced both in handmade and modern ways. It takes 7-10 days to complete a piece of batik fabric according to the order of buyers. The process of making batik consists of four stages, namely drawing patterns, giving wax, coloring, and filling colors. Tuban Batik Center has a sales market of 60% local and 40% for out-of-town shipments. The batik center has 45 workers with a working duration of 9 hours/day. In producing batik, it takes about 10 days to complete one batik cloth. Gedog batik has partners in the Java and Bali regions, they are regularly consumers of Gedog batik. Production continues without holidays or full time (Monday - Sunday) because the demand continues to increase. Workers must doing extra work hours to finish the job because too many orders have made. The workers and owners of Tuban batik center often do not consider ergonomic aspects when doing work. Consequently, workers often experience pain in the body which is called work musculoskeletal disorders (Finsen et al., 1998).

Figure 1. Example posture of workers in workplace

From the interviews to workers, 90% of the workers carry out their work without considering ergonomics or work safety aspects and had complain about fatigue. The position of the craftsmen during work is sitting with a tendency to bend over and stand up repeatedly, according to the type of work. It is categorized as a static type of work and can result in work-related musculoskeletal disorders (WMSD) (Punnett & Wegman, 2004). From the data obtained, the temperature level of the batik working conditions is 31 ºC, this is because many of the stoves are lit and the ventilation is lacking so the temperature there is hot and stuffy A stuffy and hot work environment, because it only relies on solar lighting and existing ventilation without adding tools, can lead to fatal consequences for workers, such as causing the risk of work accidents and increasing stress for workers as the work environment is not up to standard (Finsen et al., 1998). The lack of personal protective equipment and worker awareness about occupational health and safety (OHS), such as the use of gloves, is something trivial but frequently violated by workers. This is very risky in the short and long term but is not realized by workers, while it can affect the performance of the employees (Finsen et al., 1998). From figure it can be seen that workers at work sitting with a tendency to bend over and worker did not use Personal Protective Equipment (PPE) in hot environment.

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For the problems faced by the Batik Gedog Tuban Industry Center, one of the most appropriate methods to identify problems with these conditions is the participatory ergonomics approach. According to Van Eerd et al. (2010), participatory ergonomics is to fix working conditions, where workers are invited to think and take action related to improvements or interventions that will be carried out by researchers (Hess et al., 2004). Participatory ergonomics can reduce the risk of work fatigue caused by work-related musculoskeletal disorders (Aznam et al., 2017). Participatory ergonomics is one of the process approaches used to implement ergonomics intervention programs (Nurmianto, 1996). The process of participatory ergonomics evaluation program is to prevent fatigue-related disorders at work (Driessen et al., 2010). Fatigue-related disorders are influenced by sleep history, working time, length of awake time, and work position (Dawson & McCulloch, 2005; Puteri & Sukarna, 2017). The condition of the physical work environment can affect work productivity and safety, while it can be solved with a participatory ergonomic approach (Wardana et al., 2019). The physical work environment is everything around the workers that affect themselves in carrying out the assigned tasks, for example, lighting, temperature, and noise (Nitisemito, 2002; Restuputri et al., 2019). Participatory ergonomics can reduce the risk of work accidents by using personal protective equipment from things caused by human errors (Ikasari et al., 2018). Motamedzade et al. (2003) state in their research that participatory ergonomics can reduce the risk of work accidents and affect work productivity. Several studies that use participatory ergonomics are Rasmussen et al. (2017) which uses a sample of elderly workers and Eaves et al. (2016) who examined construction workers. Besides, there are researches on the use of participatory ergonomics to reduce the risk of MSD's (Svendsen et al., 2020; Van Eerd et al., 2018), the use of participatory ergonomics in manufacturing (Zare et al., 2020; Dian et al., 2016; Tappin et al., 2016), and the use of participatory ergonomics for design (Mackrill et al., 2017; Zhou et al., 2016). Therefore, a participatory ergonomic approach can be used to reduce the risk of work accidents and increase work productivity.

RESEARCH METHODS

Based on problem identification, field studies, and literature studies, the data collection and processing stages are carried out, as well as analysis for the proposed working conditions using a participatory ergonomic approach. The results are expected to help companies reduce the risk of work accidents. The stages in the participatory ergonomics method are as follows:

A. Analyzing the System

This phase includes an analysis of the current situation at the time of the research, as well as the condition of the Batik Gedog Tuban industry center. In this phase, the analysis of factors that cause the risk of work accidents is carried out. These are factors to analyze:

1. Work fatigue factor
   At this stage, Nordic body maps questionnaires given to employees who work in the production section to find out workers' complaints regarding work positions (Corlett, 2005). In this step also calculate work posture risk analysis using OWAS (Ovako Work Posture Analysis System). OWAS method can detect whether work posture is dangerous for workers to the maximum level (Karhu et al., 1981) .
2. Physical work environment factors
   Two factors were analyzed at this stage, namely the lighting level (lux) and room temperature (°C). Both environmental factors affect work accidents but increase work productivity at once (Wardani, 2003).
3. Assessment of some selected organizational indices such as the productivity calculation
4. OHS Occupational Health and Safety factor
   At this stage, observations are made regarding the work accident history experienced by workers. After that, an analysis is carried out related to the personal protective equipment used when doing work. Personal Protective Equipment (PPE) is very important for workers to avoid the risk of work accidents (Putri & Yustinus Denny, 2014).

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B. Ergonomics Awareness

In this study, the framework used is the *Participatory Ergonomics Framework* (Hignett et al., 2005). The framework is implemented so that the participatory ergonomic approach process can run according to the desired goals. In this work system design analysis, decision making is carried out in consultation with individuals and groups. Participants or members of the ergonomics team consist of researchers, company owners, workers, and supervisors. The total population and participants in this study amounted to 45 people. All the participants here are the workers on the production line.

The process of participatory ergonomic approach is a part of ergonomics that emphasizes active participation by related parties. In this study, the related parties joined the ergonomics team. The active participation is manifested in the form of Focus Group Discussions (FGD) or groups where all parties describe the problems and together look for ideas and concepts for problem-solving (Haines et al., 2002). The groups were carried out three times with respective objectives, namely:

1. First stage FGD: Identifying and describing existing problems, as well as accommodating improvement suggestions from ergonomics team members.
2. Second stage FGD: Each member of the ergonomics team provides concept suggestions, as well as discusses alternative designs and improvement suggestions.
3. Third stage FGD: Evaluating the tested work system design improvements and making suggestions for additional improvements.

The framework is implemented so that the participatory ergonomic approach process can run according to the desired goals. In this work system design analysis, decision making is carried out in consultation with individuals and groups. Participants or members of the ergonomics team, namely researchers, company owners, workers, and experts. The participatory ergonomics framework in this study can be illustrated in the figure 2.

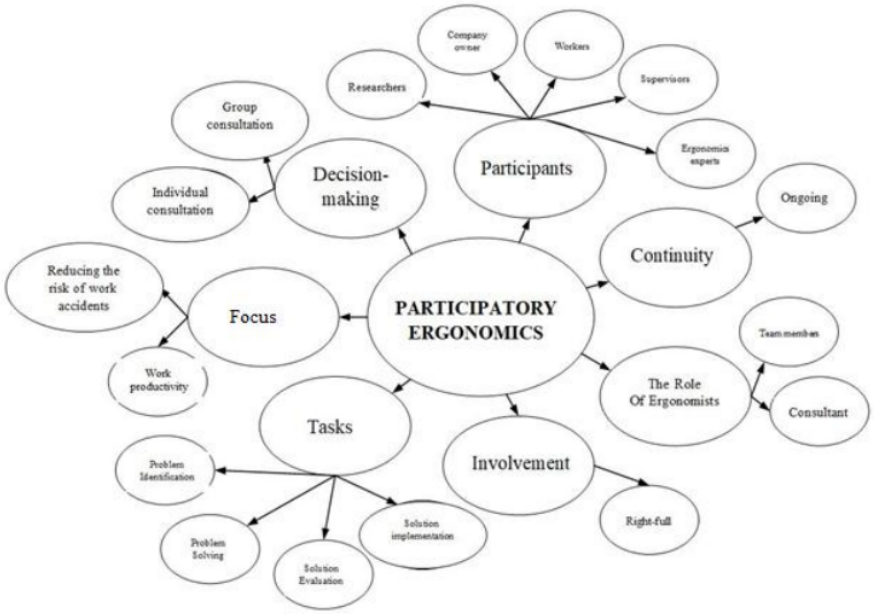

Figure 1. The participatory ergonomics framework

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C. Solutions

The steps for emerging solutions include 3 stages. The first stage of distributing questionnaires by was carried out to determine the comfort of workers related to the suggestions given according to the participatory ergonomic aspects that the solution was thought by the team, here the workers were fully involved to determine from the 3 aspects that had been proposed by the ergonomics team previously. The second stage is selecting aspects based on the results of questionnaires that have been distributed to workers, then processed using SPSS to select the best aspects according to workers. The third stage makes improvements according to the selected aspects, this stage the ergonomics design team plays an important role before improving working conditions. Which is where making an ergonomic work layout is then discussed with the owner of the company before improving working conditions. The following are the results of the working conditions.

RESULTS AND DISCUSSION

A. Identifying the Musculoskeletal Pain

In identifying work fatigue, a Nordic Body Maps questionnaire was used to determine which work postures are at risk of work accidents. Then the completion is carried out according to the method according to the results of the questionnaire. Table 1 shows the results of the Nordic Body Maps questionnaire distributed to workers. This is conducted to find out the work postures that are at risk of experiencing muscular work disorders.

Table 1. The results of the Nordic Body Maps questionnaire

No	Kind of Complaints	A (Pain)	B (No Pain)	The Percentage of Complaints
0	Upper Neck	40	5	89%
1	Lower Neck	35	10	78%
2	Left Shoulder	30	15	67%
3	Right Shoulder	39	6	87%
4	Left Upper Arm	10	35	22%
5	Back	39	6	87%
6	Right Upper Arm	40	5	89%
7	Waist	44	1	98%
8	Hip	40	5	89%
9	Buttocks	39	6	87%
10	Left Elbow	20	25	44%
11	Right Elbow	41	4	91%
12	Left Forearm	19	26	42%
13	Right Forearm	38	7	84%
14	Left Wrist	36	9	80%
15	Right Wrist	43	2	96%
16	Left Hand	37	8	82%
17	Right Hand	40	5	89%
18	Left Thigh	20	25	44%
19	Right Thigh	25	20	56%
20	Left Knee	22	23	49%
21	Right Knee	25	20	56%
22	Left Calf	23	22	51%
23	Right Calf	25	20	56%
24	Left Ankle	10	35	22%
25	Right Ankle	10	35	22%
26	Left Food	5	40	11%
27	Right Foot	5	40	11%

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After knowing the results of the Nordic Body Maps questionnaire that some of the workers' postures experience complaints or illness while doing work. Most of workers feel pain in the upper body this can be seen from the NBM results, more than 90% workers feel pain in waist, right elbow, and right waist, more than 80% workers feel pain in upper neck, right shoulder, right forearm, back, hip, right upper arm, wrist, buttock and hand, and more than 70% feel pain in lower neck.

After obtaining the results of the questionnaire, an analysis is carried out using the Ovako Work Posture Analysis System (OWAS) method. OWAS is used to analyze work postures with the risk of work accidents. According to Nwe et al. (2012), OWAS method can detect whether a work posture is dangerous for workers to the maximum level. Table 2 shows the recapitulation results of the OWAS method.

Table 2. The recapitulation results of OWAS method

BACK	**ARMS**	**1**			**2**			**3**			**4**			**5**			**6**			**7**		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
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	2	2	2	2	1	1	1	1	1	1
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	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	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	1	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	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

After completing the work posture analysis by using the *Ovako Work Posture Analysis System (OWAS)* method, the result obtained was category 2. It means that some work postures of batik workers are dangerous for the *musculoskeletal* system as it resulted in a significant effect of tensions. Therefore, some improvements are needed in the future. The solutions offered are guidance on correct work posture when doing work and work aids that reduce the risk of musculoskeletal disorders. This solution is to reduce the risk of work accidents and increase worker productivity. The batik work desk is a tool that can reduce work musculoskeletal disorders.

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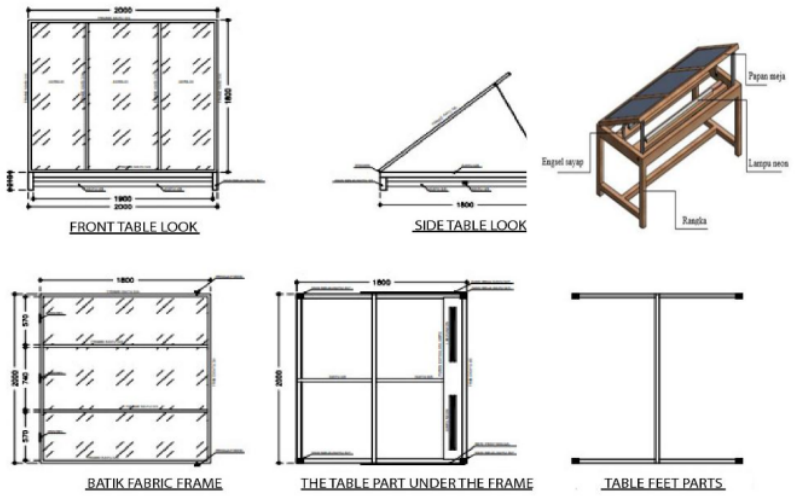

Figure 2. Work tools design

B. Identifying the Physical Work Environment

There are two aspects to consider in identifying the physical work environment of the batik industrial centers, namely the lighting level and environmental temperature. The two aspects must be well-noticed according to ergonomic standards and government regulations. The figure 4 is the result of the lighting level of the batik industry center.

Batik center only relies on lighting from ventilation that comes from sunlight. If the weather is cloudy, the batik process is very disturbing so that the lighting level is less effective. The maximum lighting level of 77 lux is located near a vent or light source, while the minimum one is 33 lux as it is located far from the light source and the average is 71 lux. Therefore, the lighting is not evenly distributed.

Figure 3. The condition of lighting level

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The solution offered for the lighting problem in batik center is the addition of lamps as lighting and not relying only on sunlight through ventilation. The lamp required 300 watts to achieve an ergonomic standard of 300 lux. The equation 1 is the formula to determine how many lamps that will be used (Faridha et al., 2016).

$$N = \frac{E \times L \times W}{\emptyset \times LLF \times Cu \times n} \quad (1)$$

Explanation:
N = The number of light points
E = Light strength (Lux), 300 lux for batik industry
L = Length of the room (in meters)
W = Width of the room (in meters)
Ø = The total value of the lamp lighting in LUMEN units (50 watt x 100 Lumen = 5000 lumen)
LLF = Light Loss Factor, the common value is between 0,7–0,8
Cu = (Coeffesien of Utillization) (0,5 – 0,6)
n = The number of lights in one point

$$N = \frac{300 \times 8 \times 6}{5000 \times 0.8 \times 0{,}6 \times 1} = \frac{14400}{2400} = 6 \text{ lamps}$$

Based on the calculation above, it is known that a batik room requires 6 lamps different light points. So, the number of energy needed is 6 x 50 Watts, or 300 Watts, to reach the desired standard.

C. The Environmental Temperature Level of Batik Industrial Centers

The solution offered for the environmental temperature problem in batik center is adding fans to reduce high temperatures, such as a fan. It needs to be placed in every corner of the room to reach the ideal temperature. According to Wignjosoebroto (2008), a good temperature in the workplace to provides high work productivity is between 24 ºC to 27 ºC. Hence, the solutions offered can increase the productivity of the workers and reduce the risk of work accidents.

D. Identifying the OHS

Based on the work accident data obtained from the Tuban batik center, most of the work risks caused by human errors are due to the lack of use of gloves as a means of personal protection equipment. Use of protective gloves typically cause the hands to perspire. Protective gloves are necessary when chemical exposure to the skin would otherwise result in adverse health effects, namely irritant dermatitis, allergic sensitization, or systemic toxicity(Klingner & Boeniger, 2002). This is a fatal thing that must be fixed by workers to reduce the risk of work accidents. The following are conditions for batik workers who neglect the use of personal protective equipment.

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Figure 4. The condition of a batik worker

Based on the problem, workers do not consider OHS aspects in their work so that it can lead to the risk of work accidents. The solution offered is the use of personal protective equipment such as rubber gloves to protect against clothing dyes which have the risk of short and long term work accidents. Rubber gloves have a thick texture and can withstand dyes so that they can reduce the risk of work accidents caused by human errors (Sugarda et al., 2014). Glove use has been shown to reduce the risk of an acute occupational hand injury by about 60% in two controlled studies (Hertz & Emmett, 1986; Sorock et al., 2004a). However, in two large studies of acute hand injury at work, 72 and 81% of injured workers reported not wearing gloves at the time of the injury (Sorock et al., 2004b).

E. Proposed Working Conditions

There are three aspects of the solution obtained. Before proposing working conditions, a discussion or interview is conducted with the participatory ergonomics team under their fields to get the best results. In this study, not all aspects of working conditions were improved in proposing ergonomic working conditions. However, there will be a selection of aspects to determine which ones have the most influence to reduce the risk of work accidents. This is in accordance with the results of the FGDs that have been conducted by all parties. Table 3 show the results of the working conditions.

Table 3. Variable selection statistics test statistics

		Work Fatigue	Physical Work Environment	OHS
N	**Valid**	45	45	45
	Missing	0	0	0
Mean		7.93	8.51	7.47
Std. Deviation		1.304	1.121	1.890
Minimum		6	7	5
Maximum		10	10	10
Sum		357	383	336

Based on the results of statistical tests, it is found that the highest mean value is the aspect of the physical work environment. Therefore, it can be concluded that the most influential

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aspect according to workers is the physical work environment aspect. Furthermore, work conditions are improved with the selected aspects.

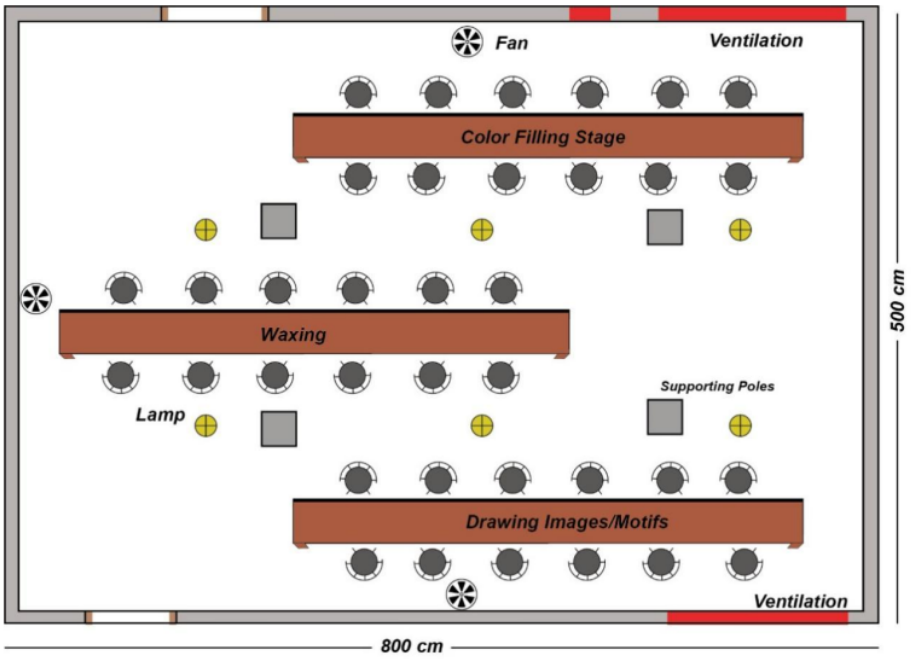

Figure 5. The proposed working conditions

Figure 6 is a design for improving the work layout that is selected based on the results of the questionnaire distributed to workers. The layout design above considers ergonomic aspects according to the standards of the Regulation of the Minister of Health of the Republic of Indonesia Number 70 of 2016 (Dermawan & Syai'in, 2017). This layout design has been considered by all parties under participatory ergonomic aspects. As for the proposal given is the addition of 6 light points with 50 watts lighting energy of each, to maximize the performance of workers to be more productive and not only rely on lighting from the sun. The second proposal is the addition of fans at 3 points to cool the room temperature according to standards. It will minimize the heat in the room and provide comfort for workers. The table layout is deliberately designed straight so that it is easy to control and distribute the work results so that it is not messy like before improvement.

F. Work Productivity

It is a productivity calculation performed before and after an improvement to determine whether the proposed improvement will increase productivity or not. The proposed improvement is following Figure 7 with the arrangement of working conditions and improvement of the physical work environment according to standards.

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Before Improvement

After Improvement

Figure 6. The layout comparison of working conditions

1. Productivity Before Improvement

Productivity is calculated based on the results of the products that have been produced. Then observations were made for 10 working days as it takes 7 - 10 working days to complete a ready-for-sale batik fabric. The following is the calculation of work productivity before improvement:

$$\text{Productivity } (\%) = \frac{\text{output}}{\text{input}} \quad (2)$$

Where:
Output = 30 batik fabric
Time Standard = 8 days
Input (Total workers x working hour)
Total workers = 45 workers
Working hour = 8 hours

$$\text{Productivity } (\%) = \frac{30 \times 8}{45 \times 8 \text{ hours}} \times 100\% = 67\%$$

Hence, productivity before improvement is 67%

2. Productivity after Improvement

The following is the calculation of work productivity after improvement:

Where:
Output = 35 batik fabric
Time Standard = 8 days
Input (Total workers x working hour)
Total workers = 45 workers
Working hour = 8 hours

$$\text{Productivity } (\%) = \frac{35 \times 8}{45 \times 8 \text{ hours}} \times 100\% = 78\ \%$$

There is an 11% increase compared to before improvement. Thus, the proposed working conditions can increase productivity and can reduce the risk of work accidents(Supriyadi & Cahyana, 2019).

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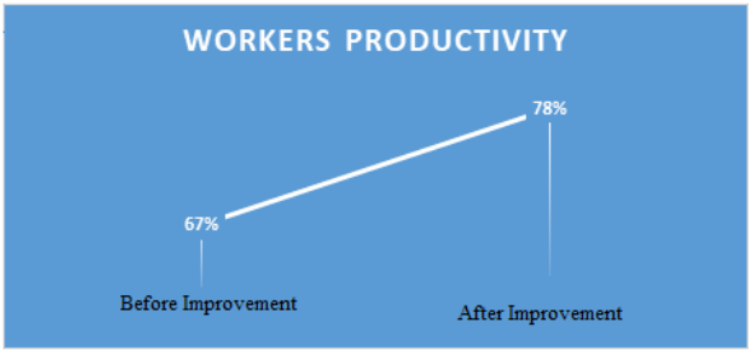

Figure 7. Productivity before and after improvement

From Figure 8 it can be analyzed that the condition before improvement, employee productivity is 67% or 30 batik cloths produced for 10 days. Many factors affect employee productivity, namely the physical work environment that does not comply with standards and the lack of attention to worker safety. However, after repairing the working conditions according to standards. The productivity of the workers itself increased by 78%. The biggest thing to be improved was in the conditions of the workplace and in the arrangement of the workspace. So that the impact on the increase in the resulting product. Therefore, the method used is not only the product produced but also the comfort of the workers when doing the work. Because it is very important to reduce the risk of work accidents caused by human error (Gibb et al., 2006).

CONCLUSION

Based on the research results, it is concluded that the type of work at risk for *musculoskeletal disorders* is the batik process. There are 12 postures are at risk of causing injury. OWAS analysis (*Ovako Work Posture Analysis System*) obtained results in category 2, namely the need to change the work posture as the previous can have a significant effect on tension and lead to *work musculoskeletal disorder*. Based on the results of the study, it was found that the physical work environment of the Tuban batik center did not match the existing standards. The lack of lighting levels can be fatal to workers and too hot temperatures can affect their comfort. Therefore, the solution offered is the addition of 6 light points with 50 watts lighting energy of each. Besides, it is necessary to add the three-point auxiliary fan to cool the room. Based on the research results, almost all work accidents are caused by human errors from workers, such as using Personal Protective Equipment (PPE). It is often neglected during work so that it can be fatal to workers (Sorock et al., 2004b). The solution that was offered was the use of long rubber gloves for the coloring process because of a large number of accidents occurred during this process. The proposed working conditions given are in the physical work environment as in the questionnaire given, workers tend to choose the physical work environment to reduce the risk of work accidents and increase worker comfort. 85% of workers want a change in the physical work environment. The productivity of workers is 67% before improvement and become 78% after improvement. It can be concluded that the solutions offered can reduce the number of work accidents and increase work comfort which affects worker productivity.

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