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Ergonomic risk evaluation to minimize musculoskeletal disorders of workers at batik cap industry

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This research was carried out in Batik Cap production in Surakarta, Indonesia. Creating and producing batik is still done manually with non-ergonomic work postures and repetitive movements that can cause musculoskeletal disorders (MSDs). The study aimed to determine the risk level of injury of MSDs in the work posture that focuses on the upper body and analyze the risk factors of muscle injury with different upper body regions. Data collection used five workstations with 22 activities for Batik Cap workers. Data analysis used the Plan for Identifiering av. Belastningsfaktorer (PLIBEL) checklist and the Quick Exposure Checklist (QEC) method. The results of the PLIBEL checklist show six activities included in the fair category, 14 in the moderate category, and two in the substantial category. The QEC method results show 20 activities in the action level 3 category, which means further investigated and changes are needed. Two activities in category 4 mean that investigation and change need to be done as soon as possible. In conclusion, the result shows that redesigning and designing work facilities is expected to reduce workers' muscle injury risk, especially in the back, neck, elbow, forearm, and hands which can cause MSDs.

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1. INTRODUCTION

Indonesia is a developing country where many Small and Medium Enterprises (SMEs) use human labor in carrying out their work. Kampoeng Batik Laweyan is a home industry for making batik cloth with a variety of products, namely: *batik tulis* and *batik cap*. The difference between *batik tulis* and *batik cap* is that *batik tulis* is made by using *canting* to apply the wax on the cloth, while *batik cap* is made by using a stamp or a kind of stamp made of copper, which forms *batik* motives. Making batik cloth is still the traditional way and uses human labor. The activity of manual material handling in SMEs was identified as risky, a cause of low back pain due to manual working, which is enough, and awkward posture at work. Other causes are heavy workload, improper posture, and high repetition of work. Some examples of health problems in batik artisans are sore hands, especially when applying wax to batik cloth, and back pain in workers who are in charge of rinsing the fabric. Physiological exposures of work in manufacturing activities are more seen in SMEs, which are prominent in generating

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disorders. The slight impact of ergonomics in reducing work accidents for SMEs in Indonesia indicates that the contribution of ergonomics researchers has not been effective [1]. Economic and social phenomena are responsible for transforming the business environment and ergonomics to improve occupational health and safety, labor productivity, and production systems [2]; the prevalence and costs of MSDs remain high [3]. These factors can reduce workers' overall productivity and lower work quality [4].

That is often found in the workplace and related to the strength and endurance of humans in carrying out their work is musculoskeletal complaints. This complaint is felt in parts of the skeletal muscles, including the muscles of the neck, shoulders, arms, hands, fingers, back, waist, hips, legs, and other muscles. MSDs are related to inappropriate workloads [5]. Symptoms of MSDs are a pain in one or more areas of the body. Accumulated minor injuries resulting from long-term and repetitive workloads can majorly cause MSDs [6]. Awkward posture, manual handling of heavy loads, repetitive movements, vibrations [7] [8], prolonged daily working, and awkward neck bending [9] are factors that have indicated the cause of MSDs. Ergonomic intervention is needed to eliminate the risk of exposure to factors contributing to MSDs on the production line. A lack of understanding of WMSDs phenomena may affect the lack of effectiveness of the intervention [10].

MSDs are complaints on muscle parts that a person feels, ranging from very mild complaints to pain. The risk of MSDs related to work is commonly reported in the literature, related to repetitive, excessive force, vibration and awkward posture [11]. According to Burdorf and Beek [12], methods for assessing the exposure to risk factor MSDs are divided into three categories: subjective judgment (e.g., questionnaire and measurement scale), systematic observation and direct measurement.

Existing studies reinforce the relationship between musculoskeletal load as a function of parameters reflected in posture, time sequence, and the onset of MSDs disease. This indicates that the workload can be reduced by developing MSDs. The biomechanical posture factor and the use of pressure (called external force) are important for documenting the factors associated with the workstation [13]. According to Motamedzade et al. [14], ergonomic risk factors initially include workstations, tools, equipment, work methods, work environment, individual worker characteristics, metabolic needs, physical stress, and emotional stress. There are several methods of ergonomic risk assessment of a job, namely: the PLIBEL checklist and the QEC Method. The QEC method is indirect, while the PLIBEL checklist is semi-direct [15].

The PLIBEL checklist was developed by Dr. Kemmlert in 1990 and was used to identify factors in the occurrence of muscle injuries that can cause dangerous effects. PLIBEL checklist is a simple screening tool to look for musculoskeletal risk factors by assessing five parts of the body that experience complaints that are felt by workers [16]. This PLIBEL checklist is applied to find the body parts that experience the biggest musculoskeletal complaints, namely at the neck, shoulder, upper back, elbows, forearm, hands, feed, knees and hips, and low back [17].

The QEC method is one of the posture load measurement methods introduced by Li and Buckle in 1998 [18]. The QEC method determines the risk of injury to skeletal muscle disorders focused on the upper body, namely the neck, shoulders, back, arms, and wrists [19]. The method advantage considers the conditions experienced by workers from two points of view, namely from the point of view of observers and workers [19]. The advantages of the QEC method are Stanton [20]: it includes several physical risk factors for WMSD, considers user needs, considers the combination and interaction of several workplace risk factors, has a good level of sensitivity and usefulness, a good level of inter and intraobserver reliability, is easy to learn and quick to use. In addition, this method has weaknesses: it focuses on the physical factors of the workplace, the exposure score in the form of an action level needs to be validated, and the need for training for beginner users [21].

Research on Batik Cap MSME was conducted by Pratiwi and Kartikasari [22] using The Posture Activity Tools Handling (PATH) method and The Ovako Working Posture Analysis System (OWAS) method, resulting in the two methods having different risk values. The highest risk value in the PATH method depends on the posture of workers affected by the most extended duration of work. In contrast, the risk value in the OWAS method depends on the recapitulation of the action level category. Research using the PLIBEL method was conducted by Sari et al. [23]

in the ceramic manufacturing industry using the NBM, OWAS and PLIBEL method, where the highest risk is identified at the raw material processing station based on the PLIBEL Checklist, namely on the elbows, arms, and hands. Another research was conducted by Jee and Lim [17] to see the sitting conditions of the students; the data were analyzed using reliability, normality, and variance (ANOVA) with SPSS version 21.0 tools.

Research using the QEC method is also conducted by Sukadarin et al. [24] on oil palm workers. It was revealed that the legs assessment was not measured. The arms and shoulders assessment was not detailed yet, and the pushing and pulling assessment was still from the assessment of the worker's perception side; therefore, the QEC method is not suitable for analyzing the postural of the oil palm plantation workers. The QEC and REBA method used by Motamedzade et al. [14] in the oil engine company showed that there is a significant relationship between the final score (r = 0.731) and the level of action (r = 0.893). Comparing the two methods' activity levels and final scores have no significant difference between departments. Research comparing eight methods is conducted by Chiasson et al. [11] to assess 224 workstations involving 567 tasks in various industrial sectors. The study using QEC and REBA methods was conducted in a steel factory with 296 workers [25]. The study showed that the highest prevalence of symptoms was in the lower back, shoulders, and neck. Meanwhile, Lin et al. [26] studied 230 dental professionals using the QEC method and work ability index (WAI) to evaluate their workability.

This study aims to determine the risk of injury to skeletal muscle disorders in the work posture that focuses on the upper body and to analyze the risk factors for muscle injury with different upper body regions. Activities that provide substantial action-level results will be redesigned for equipment and work facilities so that it is expected that the action level will decrease.

2. RESEARCH METHODS

The research was conducted in the Batik industry in Kampoeng Batik Laweyan, Surakarta, Indonesia, from January to April 2021 (4 months). Five workstations are observed in this study: stamping, coloring and color-locking, shedding wax, drying, and storing finished products. In total, there are 22 activities with 75 workers as respondents. Discussions with each worker include determining the date and time for data collection. Each respondent signed the informed consent and received a questionnaire with appropriate information sheets. After they agreed to participate and were explained the research procedure, the respondents filled out a questionnaire. The Chairperson of the Paguyuban Kampoeng Batik Laweyan Indonesia granted research permission. The ethical approval was given by the Health Research Ethics Committee, Faculty of Medicine, of Universitas Muhammadiyah Surakarta. The identities of the workers are 53 male (70.67%) and 22 female (29.33%) with an age range of 26-67 years, mean ± SD 44.18 ± 11.21 years, long-range work 2–40 years mean ± SD 15.28 ± 10.68 years, mean Body Mass Index (BMI) ± SD 24.23 ± 2.09 kg/m^2. BMI is calculated by the results of measuring workers' height and weight.

2.1. Data Collection

Data collection uses two methods, namely: PLIBEL and QEC methods. Workers fill PLIBEL checklist according to conditions felt by workers [27]. The QEC questionnaire uses observational work posture data by taking pictures in each activity. There are 22 pictures of workers when doing 22 activities called work postures.

The PLIBEL checklist questionnaire was given to workers, consisting of two questionnaires, factors on the occurrence of MSDs risks questionnaire and an environmental and organizational factors questionnaire. In the factors on the occurrence of MSDs risks questionnaire, four body parts observed have a risk of musculoskeletal injury. Each part of the body has a different number of questions. There are 26 questions for the neck/shoulder and upper back; 11 for elbows, forearms, and hands; 8 for hips, knees, and feet; and 21 for the lower back. At the same time, the environmental and organizational factors questionnaire consists of nine questions. Workers who answer the question with **'Yes'** written number 1 for the injured body part and answer with **'No'** written number 0 for non-injured body parts.

The QEC questionnaire consists of two questionnaires: the observer questionnaire and the worker questionnaire. The observer questionnaire consists of seven questions related to body parts. Starting from A to G. Assessment of observers

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uses codes from A to G, where A and B codes are back positions, C and D codes are conditions of shoulder/arm, E and F codes are the wrist/hand position, and G code is the condition of the neck. The worker questionnaire has eight questions starting from H to O. For the assessment of workers using H code is the weight, the I code is duration, J code is the strength of the hand, K code is the visual strength, L code is the driving ability, M code is the vibration, N code is the speed of work, and the O code is the stress level.

2.2. Data Analysis using PLIBEL Method

PLIBEL checklist was distributed to workers at critical workstations to determine essential body parts. Dividing the observation of the worker's body into five parts: part one consists of the neck, shoulders, and upper back. Part two consists of elbows, forearms, and hands. Part three is the foot, part four consists of the knees and hips, and part five is the lower back. Determine complaints that workers often feel by giving questions in the form of PLIBEL checklist data. Workers answer questions that have "yes" and "no" answers for each part of the body to find out the factors that can pose a risk of injury to parts of the body [16].

Determine the results of a percentage of body parts that are often injured or that can cause risk injury using formulas:

$$\text{Percentage} = \frac{Number\ of\ Yes\ answers}{Total\ of\ the\ Questions}\ x\ 100\% \quad (1)$$

2.3. Data Analysis using QEC Method

In addition, QEC considers the subjective exposure of employees to task duration; maximum weight handled, hand force exertion, vibration, visual demand of the task, difficulty in keeping up with the work and stressfulness [25], [28]. The QEC Method uses four stages of work, namely: (1) the distribution of QEC questionnaires for observers and workers, (2) the calculation of exposure scores, (3) the calculation of exposure level values, (4) the grouping of work postures to the action level using four categories [19]. Whereas in [13], there are five stages, namely: (1) self-training, (2) Observer's Assessment Checklist, (3) Worker's Assessment Checklist, (4) Calculation of Exposure Scores and (5) Consideration of Actions. In the fourth step, what is done: (a) circle all the letters that correspond to the 'observer's assessment' and 'worker's assessment' answers, (b) mark the numbers at the intersection point of each pair of letters circled, (c) calculate the total score for every part of the body. Calculation of exposure level values according to the QEC method.

$$\text{E (\%)} = \frac{X}{Xmax}\ x\ 100\% \quad (2)$$

Where X is the total score obtained for exposure to risk injury from the calculation of the questionnaire, and Xmax is the maximum total score for possible exposure.

3. RESULTS AND DISCUSSION

Sampling the stamping workstation with the stamping cloth is the workers' activity by putting a stamp on the mori cloth. The stamp made of copper has been given a motif and hot wax—the stamp weighs 2 kilograms. Hot wax will stick to mori cloth, and it is a batik motif.

3.1. Results of the PLIBEL Method

Table 1 shows the factor in the risk of MSDs using the PLIBEL checklist for two questionnaires: the occurred factors of MSDs risks and environment and organizations as dangerous. There are five body parts and 17 question items. Workers' complaints on the neck, shoulders, and upper back who answer ‘Yes’ is 13 from 26 item questions with a percentage of 50%. Workers' complaints on elbows, forearms, and hands who answer ‘Yes’ is five out of 11 questions with a percentage of 49%. Workers experience complaints on foot that answer ‘Yes’ in four out of eight questions with a percentage of 50%. Workers complain of knees and hips who answer ‘Yes’ is four of eight questions—50%—of workers who experience complaints in the lower back that answer ‘Yes’ in as many as eight out of 21 questions with a percentage of 38%. The result of the PLIBEL checklist recapitulation is the factors of MSDs risks felt by workers when workers work—using formula (1), the percentage of occurrence factors of MSDs risks (Table 1).

The result of the PLIBEL checklist on the risk factors of occurred MSDs is that the risk values of MSDs of more than 70% who answered 'Yes' are in the elbow, forearm, and hands in 3 activities, namely: pouring color mixtures, dyeing cloth into cold water, and shedding (Table 1). In the PLIBEL checklist, which is an environmental-organizational factor as the cause of the MSDs, the answer ‘Yes” does not exceed 50% of the nine questions.

Table 1. PLIBEL checklist of the occurred factors of MSDs risks (%)

Workstations	Activities	Neck, Shoulder, Upper Back	Elbow, Forearms, Hands	Legs	Knees and Hips	Lower Back	Average	Environmental and Organizations as Dangerous
Stamping	1.1. Preparation of stamp and wax tools	53.85	63.64	62.50	62.50	42.86	57.07	33
	1.2. Table setup	19.23	27.27	62.50	62.50	23.81	39.06	33
	1.3. Arranging cloth on the table	26.92	27.27	50.00	50.00	33.33	37.51	33
	1.4. Wax checking	50.00	54.55	50.00	50.00	38.10	48.53	33
	1.5. Cloth stamping	50.00	45.45	50.00	50.00	38.10	46.71	33
	1.6. Cloth folding	11.54	36.36	50.00	50.00	19.05	33.39	33
Coloring and Color Locking	2.1. Color compounding	30.77	27.27	37.50	37.50	23.81	31.37	22
	2.2. Color mixing	38.46	45.45	50.00	50.00	38.10	44.40	44
	2.3. Pouring color mixture	30.77	81.82	50.00	50.00	33.33	49.18	22
	2.4. Laying cloth	50.00	63.64	50.00	50.00	52.38	53.20	22
	2.5. Arranging the cloth before coloring	30.77	27.27	50.00	50.00	28.57	37.32	22
	2.6. Color locking	15.38	27.27	50.00	50.00	19.05	32.34	44
Shedding	3.1. Preparing hot water	57.69	54.55	50.00	50.00	61.90	54.83	33
	3.2. Dyeing cloth in cold water	69.23	72.73	62.50	62.50	66.67	66.72	33
	3.3. Shedding wax	42.31	81.82	62.50	62.50	23.81	54.59	33
	3.4. Washing cloth in cold water	61.54	63.64	62.50	62.50	57.14	61.46	22
Drying	4.1. Lifting cloth	42.31	54.55	50.00	50.00	47.62	48.89	33
	4.2. Arranging cloth in the drying place	34.62	36.36	62.50	62.50	42.86	47.77	33
	4.3. Drying cloth	26.92	36.36	62.50	62.50	33.33	44.32	33
Storing Finished Products	5.1. Measuring white cloth	50.00	54.55	50.00	50.00	42.86	49.48	33
	5.2. Cutting white cloth	26.92	36.36	62.50	62.50	33.33	44.32	33
	5.3. Folding batik cloth	30.77	36.36	62.50	62.50	38.10	46.05	33

Table 2. Results of the QEC questionnaire for observers and workers

Workstations	Activities	Observers								Workers							
		Back (static)			Shoulder, Arms		Wrists		Neck	Questions							
		1	2		1	2	1	2		H	I	J	K	L	M	N	O
Stamping	1.1.	A3	B1	B3	C1	D2	E1	F1	G1	H1	I3	J1	K1	L1	M1	N1	O1
	1.2.	A2	B1	-	C1	D2	E1	F1	G3	H1	I3	J2	K1	L1	M1	N2	O1
	1.3.	A1	B2	-	C1	D2	E2	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
	1.4.	A1	B2	-	C1	D1	E1	F1	G2	H1	I3	J2	K1	L1	M1	N1	O1
	1.5.	A2	B1	B5	C1	D3	E1	F3	G3	H1	I3	J2	K2	L1	M1	N2	O1
	1.6.	A2	B1	B3	C1	D3	E1	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
Coloring and Color Locking	2.1.	A2	B2	-	C2	D1	E2	F1	G2	H1	I3	J1	K2	L1	M1	N1	O1
	2.2.	A3	B2	-	C1	D3	E1	F1	G2	H1	I3	J2	K1	L1	M1	N1	O1
	2.3.	A1	B1	B3	C1	D1	E2	F1	G1	H1	I3	J2	K1	L1	M1	N1	O1
	2.4.	A2	B1	B3	C2	D1	E2	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
	2.5.	A3	B2	-	C1	D1	E2	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
	2.6.	A1	B2	-	C1	D1	E1	F3	G2	H1	I3	J1	K1	L1	M1	N1	O1
Shedding	3.1.	A3	B1	B3	C1	D2	E2	F1	G2	H1	I3	J2	K2	L1	M1	N2	O1
	3.2.	A3	B1	B4	C1	D3	E2	F2	G2	H1	I3	J2	K2	L1	M1	N2	O1
	3.3.	A2	B1	B4	C2	D3	E2	F2	G2	H1	I3	J1	K2	L1	M1	N2	O1
	3.4.		B1	B5	C1	D3	E2	F3	G2	H1	I3	J1	K1	L1	M1	N1	O1
Drying	4.1.	A2	B1	B3	C1	D1	E2	F1	G1	H1	I3	J2	K1	L1	M1	N1	O1
	4.2.	A1	B1	B3	C3	D1	E1	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
	4.3.	A1	B1	B4	C3	D3	E1	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
Storing Finished Products	5.1.	A3	B2	-	C1	D1	E2	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
	5.2.	A3	B1	B3	C1	D1	E1	F1	G2	H1	I3	J1	K1	L1	M1	N1	O1
	5.3.	A2	B2	-	C1	D1	E2	F1	G3	H1	I3	J1	K1	L1	M1	N1	O1

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3.2. Results of the QEC Method

The QEC questionnaire consists of observer and worker questionnaires that analyze each worker's conditions of work posture in each activity at five workstations with 22 activities. The QEC questionnaire consists of seven questions. They are related to body parts, starting from A to G. A and B codes are back positions, C and D codes for conditions of shoulder/arm, E and F codes for the wrist/hand position, and G code is the condition of the neck. Observation starts from taking pictures of the work posture of each activity. An assessment is then conducted to determine the risk of muscle injury often experienced based on the level of musculoskeletal complaints and evaluation of work posture. Table 2 shows a recapitulation of the results of the QEC questionnaire for observers.

Observation example: workstation (1) stamping with activity (1.5) cloth stamping activity the results obtained are: level A2 where the back is moderately flexed or twisted if the movement of the person works with the flexion/extension angle, turning back or bending more than 20^0 but less than 60^0. Level B1 if the body position is non-static and level B5 if the back movement is too often "very frequent" (> 12 minutes). Level C1 if the shoulder/arm position is below waist height, and D3 level is very frequent or "Very frequent" if there is a continuous movement pattern during work. The wrist is considered E1 level if the movement is limited to less than 15 from its normal posture. Level F3 if hand movements >20 times per minute and G3 level if neck position often bends (Table 2). The worker's assessment uses H for the weight of the load, I for the duration, J for the strength of the hand, K for visual strength, L for driving ability, M for vibration, and N for the speed of work. O code is the level of stress. In the cloth stamping activity, the results of the H1 questionnaire mean that the load raised by workers is less than five kilograms. Answer I2 means that the average time spent working is 2-4 hours, answer J2 means the maximum strength in one hand is 1-4 kilograms, and K2 answer means that the visual demands at work are more detailed and need precision. Answer L1 means that the workplace does not drive a vehicle, and answer M1 means that the workplace does not use a vibrating device. N2 answer means sometimes having difficulty doing the work. Answer O1 means that generally, there is no stress/pressure when doing the work.

The exposure score generated is used to calculate the exposure level value to determine the action level for the workers calculated below.

Measurement of exposure level value = $\frac{X}{X_{max}}$ x 100% = $\frac{100}{131}$ x 100% = 76%.

It means that further research and immediate changes are needed.

The results of the observer and the worker questionnaires are then calculated for the exposure score and exposure level to determine the action level and actions for changes in the body posture that are injured in the muscle. At the stamping workstation, the cloth stamping activity gets an exposure score of 131, which is the sum of eight categories (Table 3).

Table 3. Exposure score value of cloth stamping

No	Category	Score
1	Back	40
2	Shoulder/Arms	30
3	Wrists	36
4	Neck	18
5	Driving	1
6	Vibration	1
7	Work Speed	4
8	Stress	1
	Total Exposure Score	131

Table 4 shows the exposure level result generated from five workstations with 22 activities. The last column is the exposure level results from calculating the total score divided by the maximum exposure risk score for MSDs (formula 2). 2 activities have an exposure level above 70%, which is in the very high category, meaning that research and immediate change are needed [14]. Exposure levels >70% are cloth stamping and shedding.

In the cloth stamping activity, the back gets a score of 40, meaning that the exposure level is in the very high category, shoulder/arms with a score of 30 is in the high category, wrists with a score of 30 means in the moderate category, and neck with 18 is in the very high category. In shedding activity, the back gets a score of 38 which means it is at the exposure level in the very high category, the shoulder/arms with a score of 34 are in the high category, the wrists with a score of 30 means in the moderate category, and neck with 16 in the very high category (Table 4).

The lowest level of exposure to white cloth-cutting activity is 53% in the high category,

meaning further research and changes are needed [9]. In the white cloth cutting activity, the back gets 32 scores in the high category, the shoulder/arms score 22 in the moderate category, the wrists score 22 in the moderate category, and the neck scores 14 in the high category.

Table 4. Results of exposure level on QEC method

Work Stations	Activities	Observed Body Parts				Driving	Vibration	Work Speed	Stress	Exposure Level (%)
		Back	Shoulder/Arms	Wrists	Neck					
Stamping	1.1.	36	26	22	12	1	1	1	1	57
	1.2.	24	16	28	16	1	1	4	1	56
	1.3.	22	26	26	14	1	1	1	1	57
	1.4.	22	22	28	14	1	1	1	1	56
	1.5.	40	30	36	18	1	1	4	1	76
	1.6.	36	30	22	14	1	1	1	1	60
Coloring and	2.1.	26	26	26	16	1	1	1	1	60
Color	2.2.	30	30	28	14	1	1	1	1	65
Locking	2.3.	28	22	32	12	1	1	1	1	56
	2.4.	32	26	26	14	1	1	1	1	58
	2.5.	30	22	26	14	1	1	1	1	59
	2.6.	22	22	30	14	1	1	1	1	57
Shedding	3.1.	32	26	32	16	1	1	4	1	64
	3.2.	36	30	28	16	1	1	4	1	66
	3.3.	38	34	30	16	1	1	4	1	71
	3.4.	40	30	34	14	1	1	1	1	69
Drying	4.1.	28	22	32	12	1	1	1	1	56
	4.2.	28	30	22	14	1	1	1	1	56
	4.3.	32	34	22	14	1	1	1	1	60
Storing	5.1.	30	22	26	14	1	1	1	1	59
Finished	5.2.	32	22	22	14	1	1	1	1	53
Products	5.3.	26	22	26	16	1	1	1	1	58

Note: It is known that this activity needs to be researched and changed as soon as possible because ≥70%.

Table 5. Results comparison between PLIBEL score and QEC exposure level (%)

Work Stations	Activities	PLIBEL Method		QEC Method	
		Score	Action Level	Exposure Level	Action Level
Stamping	1.1.	57,07	Moderate	57	3
	1.2.	39,06	Fair	56	3
	1.3.	37,51	Fair	57	3
	1.4.	48,53	Moderate	56	3
	1.5.	46,71	Moderate	76	4
	1.6.	33,39	Fair	60	3
Coloring and Color Locking	2.1.	31,37	Fair	60	3
	2.2.	44,40	Moderate	65	3
	2.3.	49,18	Moderate	56	3
	2.4.	53,20	Moderate	58	3
	2.5.	37,32	Fair	59	3
	2.6.	32,34	Fair	57	3
Shedding	3.1.	54,83	Moderate	64	3
	3.2.	66,72	Substantial	66	3
	3.3.	54,59	Moderate	71	4
	3.4.	61,46	Substantial	69	3
Drying	4.1.	48,89	Moderate	56	3
	4.2.	47,77	Moderate	56	3
	4.3.	44,32	Moderate	60	3
Storing Finished Products	5.1.	49,48	Moderate	59	3
	5.2.	44,32	Moderate	53	3
	5.3.	46,05	Moderate	58	3

Note: Action level: Substantial

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Results comparison between the PLIBEL and the QEC method was found in Table 5. In the PLIBEL method, the PLIBEL score is obtained from 5 body parts, namely: (1) neck, shoulders, back, (2) elbows, arms, hands, (3) feet, (4) knees, hips, (5) lower back. While the exposure level of QEC is obtained from (1) observed body parts, namely: back, shoulder/arms, wrists, neck, (2) driving, (3) vibration, (4) work speed, and (5) stress. Table 5 shows that table preparation activity, arrangement of cloth on the table, cloth folding, color compounding, cloth arrangement before coloring, color locking, and white cloth cutting are safe from complaints and risk exposure to MSDs. Dyeing cloth in cold water, washing cloth in cold water, stamping cloth, and cutting white cloth are very high categories against complaints and risk exposure of MSDs and need to be immediately carried out research and changes as soon as possible.

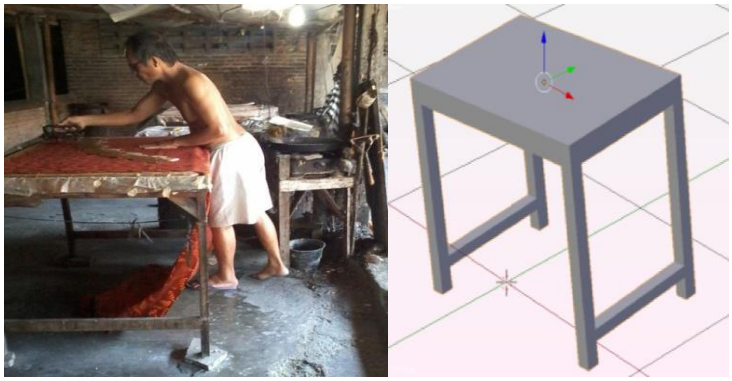
Table 5 shows that in the PLIBEL Checklist method, the fair action level is 27.27%, the moderate level is 63.63%, and the substantial action level is 9.10%. Meanwhile, the moderate action method results are 90.90%, and the substantial action level is 9.10%. For a substantial action level on the PLIBEL checklist method, there are activities of dying cloth in cold water and washing cloth in cold water at the shedding workstation. Meanwhile, a substantial action level in the QEC method is found in stamping clothing and wax-shedding activities. There are two activities with a substantial action level (PLIBEL checklist) and one with a substantial action level (QEC method). A fair action level means that the work posture is quite safe, and a moderate level means the work posture needs improvement. A substantial action level means the work posture needs immediate improvement because it is unsafe. Improvement of work posture can be done by improving working methods and procedures, designing tools at workstations, or even improving the layout of the production floor. MSDs in office workers mostly occur in the lower back, wrists/hands, and shoulders [29].

The QEC method cannot be applied permanently to workers in oil palm plantations [24] with limitations on the assessment of the leg, the analysis of the arms and shoulders and no assessment of push and pull activity, especially on tall trees. In addition, in Chiasson et al. [11] stating that QEC proved to be less rigorous in assessing overall risk, it resulted in classifying workstations with a risk of 35% for QEC compared to RULA of 76%. Comparison between the QEC and REBA methods [9] is that the QEC method assessment results in a low-risk level of 20%, a medium-risk level of 50% and a high-risk level of 30%, in contrast to the REBA method with a low-risk level of 15%, a medium risk level of 60% and a high-risk level of 25%. Thus, there is a strong correlation between identifying occupational risk and determining the potential risk of MSDs. In the brick making [30], it is necessary to design a tool for mixing the material and the operator's workbench to minimize WMSD and to reduce the exposure value by 48.8 5a and 47.7%. REBA method includes physical ergonomics [25], while the QEC method also discusses cognitive ergonomics and organization and includes employee opinions as part of the evaluation.

PLIBEL checklist, according to Sari et al. [23], high PLIBEL scores is resulted from heavy physical loads by lifting activity and the impropriety of the basket handling position that occurs in raw material processing workstation. Whereas Ng et al. [17] shows a slight correlation between the perception of table and chair arrangement and stress factors with repetitive movements, upper extremities, and working room. Static sitting posture puts you at risk for MSDs, especially in the lower and upper back. The results Ng et al. [17] indicated little association between perceptions of the table and chair placement and stress factors induced by general repetitive motion, upper limb repetitive motion, and workplace space/support. The implementation of PLIBEL and QEC methods on the oil palm plantation workers, brick-making workers, and university students showed that these two methods have different results when implemented in different workplaces as well.

3.3. Recommended for Cloth Stamping Activity

Fabric stamping activity is the highest exposure level in the QEC method in action level 4. This action level indicates that further research and changes need to be carried out as soon as possible in this activity. These activities are categorized as very dangerous to the risk of injury to skeletal muscle disorders in the upper body. The risk of injury reduction could be the design of working tools, equipment, work facilities, and non-ergonomic position. Fig. 1 shows the development of a table for fabric stamping activities.



(a) (b)

Fig. 1. Cloth stamping activity (a) Initial condition, (b) Suggested condition

Fig.1 (a) shows the stamping table's initial condition, which causes a high QEC score on the back and neck. The stamping table measures 100 cm x 90 cm x 90 cm, causing the position of the arms to be far enough to reach the front resulting in the back and neck bending and bending forward. Based on these conditions, the stamping table must be redesigned to reduce the risk of muscle injury. Fig. 1 (b) shows the condition of the suggested improvement of the stamping table according to the anthropometric data of the Indonesian people. In the stamp device's compressive strength redesign, the table height is added 15 cm from the initial size to 100 cm x 90 cm x 105 cm. After changing the size, the action level is at level 2, which is only necessary for further research without changes.

The results of the analysis of suggested improvements in four activities with hazardous scores on the PLIBEL method and QEC method are cloth stamping activity through redesign of the stamping table, cloth dyeing activity with the addition of auxiliary tools, shedding activity with assistive tools, washing cloth in cold water with the addition of aids. Redesigning and designing work facilities is expected to reduce the risk of muscle injury to workers, especially in the back, neck, elbow, forearm, and hands which can cause MSDs. It is possible to reduce the risk of MSDs and injuries by using an ergonomic work system design that integrates sit-stand chairs, hoop tables and footrests into the existing structure [31]

4. CONCLUSION

There are five workstations with 22 activities in manufacturing stamped Batik cloths in the Kampoeng Batik Laweyan. The results of the PLIBEL Method include six activities in the fair category, 14 moderate category activities, and two substantial category activities. The results of the QEC method are 20 activities in the level 3 action category. There is a need for more rigorous investigation and changes, and two category four activities must be immediately carried out and investigated as soon as possible. Redesigning and designing work facilities is expected to reduce worker's muscle injury risk, especially in the back, neck, elbow, forearm, and hands which can cause MSDs. This study can be improved by comparing several ergonomic valuation measurement methods to generate more comprehensive measurement.

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ETHICAL APPROVAL and CONSENT to PARTICIPATE

This research was approved by the Health Research Ethics Committee Faculty of Medicine of Universitas Muhammadiyah Surakarta No. 41117/B.1/KEPK-FKUMS/II/2022. We explained the aims and objectives of this research to the workers who made the batik cap. After verbal consent from participants, we distributed informed consent forms and questionnaires.

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