EVALUATION OF WORK POSTURE USING THE CTD RISK INDEX METHOD TO REDUCE THE RISK OF MUSCLE INJURY IN THE BATIK CAP INDUSTRY

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ABSTRACT

Making stamped batik goes through 5 stages, namely tasting, dyeing color, removing hot and cold tubs, and drying. This process takes place repeatedly for a long time, causing workers to potentially experience musculoskeletal complaints and the risk of Cumulative Trauma Disorders (CTDs). The purpose of this study was to determine whether batik Nilo Tirto workers were at risk for developing CTDs or not. This research was conducted by using a method to determine the level of worker complaints with a Nordic Body Map (NBM) questionnaire. After knowing each class of worker complaints, the CTDs Risk Index method is used to determine the risk score for muscle injury in workers. If the score is > 1, it is relatively unsafe, so it needs improvement. The 2 most significant scores on the CTDs Risk Index worksheet will be analyzed further to determine the risk factors for musculoskeletal use using the PLIBEL Checklist. The results obtained are, there are 2 workstations that have the highest score on the CTDs Risk Index, namely color dyeing and cold bathing. This is caused by awkward body postures when working, repetitive movements, and poor workstation conditions, so the repair needs to be done. The results of this study can be used for improvements to the workstation for dyeing color and cold tubing in the form of design proposals and the work postures of the two workers.

Keywords: *Nordic Body Map, CTDs Risk Index, PLIBEL Checklist, Cumulative Trauma Disorders.*

ABSTRAK

Proses pembuatan batik cap melalui 5 tahap, yaitu pengecapan, pencelupan warna, pelorotan bak panas dan bak dingin, serta penjemuran. Proses ini berlangsung selama berulang-ulang dalam waktu yang lama, menyebabkan pekerja berpotensi mengalami keluhan muskuloskeletal dan risiko Cumulative Trauma Disorders (CTDs). Tujuan dilakukannya penelitian ini adalah untuk mengetahui pekerja batik Nilo Tirto memiliki risiko untuk terkena CTDs atau tidak. Penelitian ini dilakukan dengan menggunakan metode untuk mengetahui tingkat keluhan pekerja dengan kuesioner Nordic Body Map (NBM). Setelah mengetahui masing-masing tingkat keluhan pekerja, menggunakan metode CTD Risk Index untuk mengetahui skor risiko terjadinya cedera otot pada pekerja, bila skor > 1, maka relative tidak aman sehingga perlu perbaikan. Nilai skor >2 pada worksheet CTD Risk Index akan dianalisis lebih lanjut untuk mengetahui faktor terjadinya risiko muskuloskeletal dengan PLIBEL Checklist. Hasil penelitian yang diperoleh adalah, terdapat 2 stasiun kerja yang memilki skort ertinggi dari CTD Risk Index, yaitu pencelupan warna dan pelorotan bak dingin, hal ini disebabkan oleh postur tubuh yang janggal ketika bekerja, gerakan berulang dan keadaan stasiun kerja yang kurang baik sehingga perlu dilakukan perbaikan. Usulan perbaikan pada stasiun kerja pencelupan warna dan pelorotan bak dingin berupa usulan desain sekaligus postur kerja dari keua pekerja tersebut.

Kata kunci: *Nordic Body Map, CTDs Risk Index, PLIBEL Checklist, Cumulative Trauma Disorders.*

INTRODUCTION

The process of making stamped batik at the Nilo Tirto Batik Industry is carried out in several steps, namely stamping the batik cloth using wax/night, dyeing the color of the cloth to give color to the fabric as a whole, sizing in a hot tub to dissolve the wax on the batik, scalding in a cold bath to remove the wax. Remove the remnants of the still attached wax and dry the cloth. This process takes place repeatedly for a long time, with manual labor, carrying heavy loads and some workers using awkward postures when working. From an

ergonomic point of view, repetitive and prolonged work activities pose a risk of CTDs [1]. Figure 1. Shows the activities during the process of making stamped batik, where each activity has a different duration. The batik stamping activity involves applying a pattern using a copper stamp repeatedly to create the desired motif, with a duration of approximately 120 minutes per piece of fabric (Figure 1(a)). The coloring activity (Figure 1(b)) involves adding color to the fabric by dipping it into a dye solution mixed with waterglass, repeated to even out the color, with a duration of 30 minutes per piece of fabric. The waxing activity for batik night immersion involves soaking the fabric in hot temperatures to dissolve the wax, with a duration of 60 minutes (Figure 1(c)), and (Figure 1(d)) immersion to remove remaining traces of wax still attached to the batik fabric, with a duration of 120 minutes. Lastly, the drying activity (Figure 1(e)) takes 350–400 minutes, depending on the weather and sunlight, to dry the batik fabric.

(a) Tasting (b) Blogging (c) Hot Tub Sliding (d) Cold Tub Sliding (e) Drying

Figure 1. The Process of Making Batik Stamp

CTDs are disorders known as repetitive strain injuries, repetitive motion disorders, and work-related musculoskeletal disorders. According to [2] the main factor in CTDs is that an awkward posture, awkward posture, and repetitive movements that are done excessively can trigger injuries due to overuse [2]. According to [4] other factors are age, gender, and chronic disease [3]. CTDs are called injuries to the musculoskeletal system, which include joints, muscles, tendons, ligaments, nerves and blood vessels [4]. Several other terms that are often used to describe CTDs include Musculoskeletal Disorders (MSDs), Work-Related Musculoskeletal Disorders (WMSDs), and Repetitive Strain Injuries (RSI) [5]. CTDs occur in upper extremity soft tissues such as tendonitis, synovitis, bursitis, carpal tunnel syndrome, sprains, and whose work often requires hand exertion [6], [7]. Occupational diseases can occur while doing work activities. Musculoskeletal complaints are the most frequently reported of the many occupational diseases [8]. CTDs can be categorized as tendon disorders and nerve disorders [4]. Musculoskeletal complaints are complaints in parts of the skeletal muscles that a person feels, ranging from very mild to very painful. If the muscles receive static loads repeatedly for a long time, it will cause damage to the joints, ligaments and tendons. This complaint is called MSDs [9]–[11]. Musculoskeletal disorders (MSDs) are injuries and disorders that affect the musculoskeletal system of human body [12]. MSDs usually occur in 9 body parts: the neck, shoulders, forearms, elbows, lower back, waist, wrists, thighs, and knees [13].

To identify the risk of muscle injury and find solutions to the problems experienced by workers in the Nilo Tirto Batik Industry, a research was conducted using a Nordic Body Map questionnaire to find out workers' body complaints, then assessing body posture and measuring the level of injury risk using the CTDs Risk Index method approach to knowing the level of risk that can occur in a work activity, for conditions that can be said to be safe, the index value must be less than one [14] and a PLIBEL Checklist assessment that focuses on identifying risk factors for musculoskeletal injury for certain body regions and only questions relevant to region of the body that needs to be answered [16]. The two methods, namely the CTDs risk index and the PLIBEL checklist, are used to assess work posture and determine what factors are MSDs for workers in the Nilo Tirto Batik Industry [15]. The two

methods, namely the CTDs risk index and the PLIBEL checklist, are used to assess work posture and determine what factors are MSDs for workers in the Nilo Tirto Batik Industry.

Research related to the CTDs Risk Index, PLIBEL Checklist and Nordic Body Map methods has been carried out by [17] who examined operators who produce plastic bottles and obtained a score of 1,996, which indicates the risk of cumulative injury at the operator's work station. [18] conducted a study on granite installation workstations using Nordic body map to determine 2 critical operators, CTDs Risk Index to determine essential stations of work and PLIBEL checklist to determine crucial parts of the body. The results obtained show that the most significant score and requires improvement is at the station granite installation work with a CTDs Risk Index score of 3.13, and on the PLIBEL Checklist, the large parts are on the neck, shoulders and upper back. [15] conducted research using Job Analysis, CTDs Risk Index, and Workstation Evaluation Checklist to evaluate MMH in companies' pushing, pulling, carrying, lifting movements. This study showed that the most experiencing problems were manual sealing and packing work which had posture clumsy back, then a proposed improvement was made in the form of a re-design of the problematic work station. [19] has researched ergonomic risk identification using the Nordic Body Map method on clothing screen printing convection workers. The results of this research are that 2 screen printing operators have average scores, namely 65 and 57 on the Nordic Body Map, which means they need improvement in the future. [20] researched workstation improvement design at PT. Karsa Wijaya uses the PLIBEL checklist and QEC methods. The study results show that the cutting and finishing operators need to make improvements by re-designing the workstation, namely making tables for both operators

The purpose of this study is to identify the presence of workers who experience CTDs disorders, and how much influence workstation conditions have on workers who have a risk of musculoskeletal fatigue in the Nilo Tirto batik industry and provide suggestions for improvements.

METHODOLOGY

Research Object

This research was conducted at the Nilo Tirto Batik Industry, located at Surakarta, Indonesia. The researcher took a sample of 4 workers at the batik stamp-making workstation. The work stations studied were 5 work stations, namely batik tasting, color dyeing, waxing in a hot tub, waxing in a cold tub, and drying. Body position when working is standing.

Anthropometry

According to [21]. Anthropometry is a study related to the measurement dimensions of the human body. Anthropometric data will determine the exact shape, size and dimensions related to the product designed with humans as the operator of the product/tool. Several factors will affect the size of the human body. Anthropometric data is obtained from the Perhimpunan Ergonomi Indonesia (PEI) in website, specifically from https://antropometriindonesia.org/index.php/detail/artikel/4/10/data_antropometri. The anthropometric data used include: body height, shoulder height, elbow height, hip height, hand length, elbow span length, and lateral hand span length.

Nordic Body Map (NBM) Method

In the NBM questionnaire, workers can do a checklist of each body part that determines the musculoskeletal complaints experienced by workers. By using this questionnaire, we will emphasize the part of the muscle that has complaints with various levels of symptoms, ranging from no pain with a score of 1, mild pain with a score of 2, pain with a score of 3 to very sore with a score of 4 [22]. There are 27 body parts examined on

the NBM, including the secular muscles on both right and left sides of the body starting from the upper limbs, namely the neck muscles to the leg muscles [16].

CTD *Risk Index* Method

The CTDs Risk Index is a CTDs risk assessment model for predicting the incidence of injury developed by Seth et a [17]. The CTDs Risk Index analysis summed the risk values for the three main causal factors into one risk score. For a relatively safe condition, the index must be less than one [14]. In the CTDs Risk Index, there are 3 main factors, and 1 additional factor studied: frequency factors, posture factors, force facts, and various factors. Frequency factors, to obtain a frequency score for work by counting the number of grasping (or catching) movements during one cycle time [18]. Force factors: To get a force factor score, compare the load lifted when doing work with the maximum load raised when doing the same job [19]. Posture factors seem awkward or awkward positions used by workers when doing their jobs. This awkward posture is essential because awkward postures can lead to fatigue [18]. An additional factor is miscellaneous factors. Other factors are the factors that have the most significant environmental impact on CTDs [18]. Much as vibration, temperature, use of gloves, work static, dynamic or intermittent, and the intensity of the worker to always be in contact with objects at acute angles [19].

PLIBEL *Checklist*

PLIBEL (Plans for Identifiering av. Belastnings Factorer) was created by Dr. Kemmlert in 1990 [20], [21]. The PLIBEL Checklist method has been used in several studies in ergonomic workplaces and as an educational tool [15]. Workplace assessment using PLIBEL begins with interviews with workers and conducting initial observations. PLIBEL is used to identify risk factors for musculoskeletal injury for specific body parts, and only questions relevant to that body part need to be answered [15]. Analysis of risk factors for musculoskeletal injury with the PLIBEL checklist method was carried out by looking back at the questions on the PLIBEL Checklist data that had the answer "yes" for each body, to find out the factors that could cause body parts to experience a level of risk of injury, the consequences that these factors could cause. And suggestions that can be made [22]. To determine the percentage results in body parts that are frequently injured or that may pose a risk of injury or that may pose a risk of injury, use the formula (see equation 1) [20]:

$$Presentase = \frac{Number\ of\ Answers}{Total\ Questions}\ x\ 100\% \quad (1)$$

The results of the PLIBEL checklist assessment will be grouped based on the action level in the form of kappa statistics to determine the following action to be taken. This grouping is based on the value generated in the calculation of the PLIBEL checklist. Table 1. is the action level of kappa statistics.

Table 1. Action Level by Kappa Statistics [23]

Score	Action
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

RESULTS

Assessment to determine musculoskeletal complaints in all workers using a body map on the NBM which is divided into several parts depending on the discomfort experienced by the worker [24]. The tasting work station obtained the highest score results with a score of

50, color dyeing with a score of 51, and sag with a score of 52, where the score is included in the likert scale at a moderate level, which requires future action. Table 2 is a recapitulation of calculations using NBM.

Table 2. Recapitulation of NBM Calculation Results

No	Complaint Type	Complaint Rate															
		Tasting				Dyeing				Sag				Drying			
		P	MP	S	PF	P	MP	S	PF	P	MP	S	PF	P	MP	S	PF
1	Pain/stiffness in the upper neck		2				2				2				2		
2	Pain/stiffness in the lower neck		2					3			2				2		
3	Pain in left shoulder		2					3			2			1			
4	Pain in right shoulder		2					3			2			1			
5	Pain in left upper arm			3				3			2				2		
6	Pain in the back		2					3				3		1			
7	Pain in right upper arm			3				3			2				2		
8	Pain in the waist		2					3				3			2		
9	Pain in the buttocks	1				1					2			1			
10	Pain in the ass	1				1					2			1			
11	Pain in left elbow	1				1				1				1			
12	Saki on right elbow	1				1				1				1			
13	Pain in left forearm	1					2				2			1			
14	Pain in right forearm			3			2				2			1			
15	Pain in left wrist	1						3			2				2		
16	Pain in right wrist			3				3			2				2		
17	Pain in left hand	1				1					2			1			
18	Pain in right hand			3		1					2			1			
19	Pain in left thigh		2			1					2			1			
20	Pain in right thigh		2			1					2			1			
21	Pain in left knee	1				1				1				1			
22	Pain in right knee	1				1				1				1			
23	Pain in left calf		2			1					2			1			
24	Pain in right calf		2			1					2			1			
25	Pain in left ankle		2			1				1				1			
26	Pain in right ankle		2			1				1				1			
27	Pain in left leg		2				2				2			1			
28	Pain in right leg		2				2				2			1			
TOTAL		50				51				52				35			

Description: P = Painless, MP = Moderate Pain, S = Sick, PF = Pain Full

After determining musculoskeletal complaints in all workers, an assessment of work posture is carried out for all workers to determine workers who are at risk of muscle injury (CTDs). Table 3. Shows the results of the recapitulation of workers who are at risk of experiencing CTDs.

Table 3. Recapitulation of CTD Risk Index Calculation Results

No.	Workstation	Frequency Factor	Posture Factor	Force Factor	Miscellaneous Factor	CTD Risk Index
1.	Tasting	0.170	0.5	0.030	0.67	0.210
2.	Color Dyeing	0.040	1	26.6	1.00	8.392
3.	Sag					
	Hot tub sag	0.021	0.5	2.1	0	0.786
	Cold tub sag	0.103	0.5	4	0.33	1.414
4.	Drying	0.038	0.2	2.2	0	0.765

Based on the recapitulation table of the results of the CTDs risk index calculation, it is known that the total score for tasting is 0.210, for immersion is 8,392, for hot tub sinking is 0.786, cold tub sinking is 1,414, and drying is 0.765. a score of > 1 was found in the color dyeing and hard bath work stations. It proves that the workers at both workstations have an injury risk level that is at risk of developing CTDs or the threat of muscle injury. For a relatively safe condition, the score must be less than one (1) [14].

Color dyeing and cold bath sag workstations with a high injury risk score, then analyzed the risk factors for MSDs using the PLIBEL Checklist. The recapitulation of risk factor scores for MSDs and environmental and organizational factors at the color tasting station and cold tub sinking are shown in table 4 below.

Table 4. Recapitulation of MSDs Risk Factor Scores

	Neck, Shoulders and Upper Back (%)	Elbow, Forearm, Hand (%)	Foot (%)	Knees and Hips (%)	Lower Back (%)
Color Dyeing	46.15	54.54	25	25	47.61
Cold Tub Sliding	50	45.45	37.5	62.5	38.09

Table 5. Recapitulation of Environmental and Organizational Factors Scores as Factors Causing MSDs

Work Station	Skor (%)
Color Dyeing	22
Cold Tub Sliding	22

Based on the results of the calculation of the MSDs Risk Factors Score, it is known that the highest score in color dyeing is on the elbows, forearms and hands because color dyeing workers use their hands more often to do their work, namely lifting, dyeing, and to turn batik cloth on dipping tub over and over again. In the cold tub slump, it is known that the high score lies in the knees and hips-several other factors, such as workers moving from one place to another to lift the batik cloth. The neck, shoulders, and upper waist are also prominent because the floor surface is not flat and slippery when working, and the tub is too short. Hence, workers have to bend over often to finish their work.

Based on the results of Environmental and Organizational Factors as Hazard Causing Factors for MSDs, it is known that the color dyeing station and cold tub sag have the same cause in the working environment conditions, namely being in conditions of coldwater temperature and pressure at work.

DISCUSSION

Improvements are made to the workstation because the workstation affects the posture conditions of workers in doing their work.

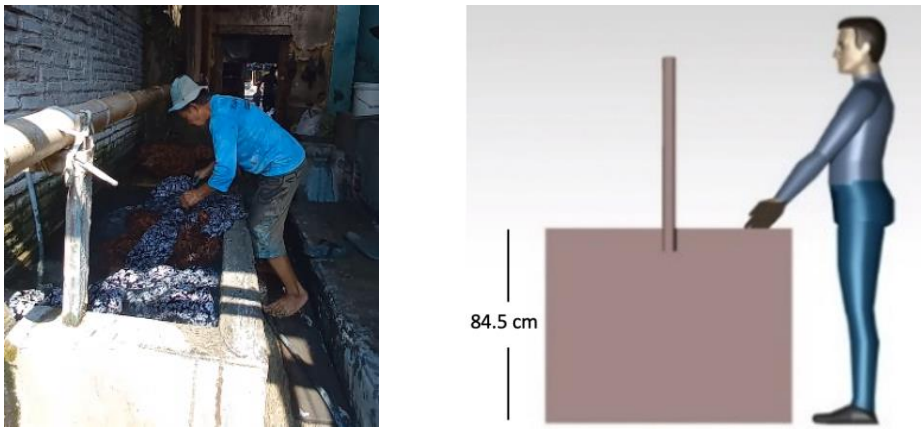
(a) Initial Condition Posture (b) Repair of Work Tools and Posture

Figure 2. Color Dyeing Process Activities

Figure 2-(a) depicts the starting working conditions of a color dyeing worker; the high CTDs Risk Index score is due to the worker's physical labor and heavy loads, resulting in a force factor of > 1, or 26.6. The heavy load being carried is fabric. Batik is being dyed and dried repeatedly on a drying pole, requiring the worker to bend down to lift the material and drain it on the drying pole above it. When the worker is working, his posture appears to be bowed. Several factors contribute to musculoskeletal risk, according to the PLIBEL checklist's findings. A significant portion is located in the neck, shoulders, and upper back, as well as the elbows, forearms, and hands, and the lower back. This is due to the fact that the exercises mostly engage the upper body and the utilization of physical power.

Figure 2-(b) results from the proposed improvement of the color dyeing workstation,

aiming to reduce the CTDs risk score. In the proposed revision, additional rollers and rollers are added to reduce the dyeing workers lifting the batik cloth continuously to lessen the force factor burden of these workers, the process of using the proposed repair work tool is by placing the fabric on a cloth roller and then tying each cloth at the end of the roller. The worker will hold the roller player to rotate the material until the fabric can be fully immersed. The center of the fabric, which is in the middle of the tub, has a retaining stick so that when the fabric is dyed, it will be held by the weight of the remaining stick. The roller that functions as a player will reduce the burden on workers because the roll that is rotated is not as heavy as lifting heavy piles of cloth. The height of the rollers is aligned with the workers' shoulders with a height of 65.19 cm following anthropometric data to facilitate dyeing work and minimize bending movements of workers when dyeing fabrics. After being simulated using the CTD Risk Index worksheet, the original score of 8,392 changed to 1,063. This proves that the proposed improvement can reduce the CTDs risk score for color dyeing workers.



(a) Initial Condition Posture (b) Posture Improvements and Work Tools

Figure 3. Sludge Process Activity in Cold Tub

Figure 3-(a) is the initial condition of the sloughing worker in a cold bath. In the proposed improvement, the container's height is adjusted to be accessible to workers. The initial height of the container is 30 cm, and the improvement involves adding height to the container, making it 84.5 cm, so that workers do not have to bend over. In the process, the worker takes the cloth from the hot tub and then dips it into the cold bath to remove the remaining wax, then the worker checks the fabric that has been soaked for a while by lifting the material little by little to prevent wax that is still attached to the material. During the inspection process, as shown in the picture, it is known that the worker's posture is bent with knees slightly bent against the wall of the tub. The cold tub is very short, so workers have to bend down to dye and check the tub cloth to soak the fabric. The inspection did not last for a short time because it took precision to see if the material still had wax residue. Based on the CTDs Risk Index worksheet, the posture factor section has a score of 0.7, which is close to 1 and the force factor with a score of 4, a posture that repeatedly bends for a long time and holds a cloth that is not light can cause the risk of injury to the upper body, so it needs to be repaired to prevent muscle injury. Other causative factors that can be seen from the PLIBEL checklist are that the floor at the work station sag is uneven and slippery, so the feet of workers must be careful when stepping. This also affects the knees and hips of workers when moving cloth which causes a score on the knees and hips get more extensive.

Figure 3-(b) is the result of the proposed repair of the cold tub sinking work station in the proposal to change the height of the tub so that it can be easily reached and reduce the worker's slouching posture. The initial height of the tub was 30 cm, then improvements were

made to adjust the size of the Indonesian anthropometric data. The tub's height was increased to 84.5 cm with the results of the progress as shown in the picture. After doing a simulation on the CTDs Risk Index worksheet, the original score of 1.4140 changed to 1.3538. This proves that increasing the height of the cold sink will reduce the CTDs risk score for the worker. This suggestion can help workers not to bend down too deeply when working to reduce the risk of back injury.

The suggestion of improvements to the batik-making workstation with problems is also in line with [25], The design of improvements to the working conditions of the pelorodan operator can reduce the risk of musculoskeletal injury. [26] by making dyeing tools and fixation of natural dyes on batik, which makes the dyeing tools more practical and efficient compared to the previous manual tools, that these repair tools can increase the dyeing capacity.

CONCLUSIONS

Two workstations have a risk of CTDs, namely color dyeing and cold tub sag, based on the CTDs Risk Index score results. Factors that influence the risk of CTDs are awkward body postures when working, such as bending over and repetitive movements for a long time, and poor workstations. Proposed improvements are made by designing the workstation using anthropometric data to suit the worker's body. This improvement proposal is expected to change the work posture of workers to reduce awkward postures.

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