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Postural Evaluation and Hand Activity Level at Batik Cap Process using LUBA and ACGIH HAL Methods

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Abstract*: *The process of making Batik Cap in Batik 'Supriyarso' exposed to workers complaints of musculoskeletal disorders (MSDs), particularly on neck, shoulder, back, arms, wrists and hips. The present study evaluates the ergonomic risks at the hand activity level by using The Postural Loading on The Upper Body Assessment (LUBA) method and The American Conference of Governmental Industrial Hygienists-Hand Activity Level (ACGIH HAL) method. The object of research is five workers with a range of 48-64 years of age who work in the cap printing process. Determination of work activities using the LUBA method there are 14 activities and the ACGIH HAL method is available 13 activities. The results of data processing are done using Shapiro-Wilk Test, Spearman Test, Mann Whitney Test within Statistical Product and Service Solutions (SPSS) Version 21.0. The ergonomic evaluation using LUBA method obtained a mean risk value of 3, showing the risk is need for immediate corrective action. Meanwhile, the ACGIH HAL method obtained a mean risk value of 1, showing the risk is acceptable and no corrective actions are needed. Based on the ACGIH HAL method, repetitive motions are influenced by work speed and work fatigue, exposing the risk of MSDs. The worker's right hand has higher risk compared to the left hand. In conclusion, the results shows that recommendation, working methods should be revised and supporting tool can be utilized to reduce muscle fatigue caused by repetitive motions.

Keywords*: *LUBA, ACGIH HAL, Ergonomic Evaluation, MSDs, Batik Cap Process.

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I. INTRODUCTION

The number of Indonesian Micro, Small and Medium enterprises (MSMEs) has increased significantly in the recent years, leading to a considerate and higher rate of labour absorption, including in the industries of Batik Cap. The process of making Batik Cap is relatively time-consuming, and it inevitably entails heavy workload, repetitive tasks, non-ergonomic posture, static sitting and bending, considerable energy, and the vibration of the whole body. However, awkward, extreme and repetitive postures in work-related activities have been linked to discomfort and injury to the lower back [1]. Moreover, [2] reported that the Iranian workers mostly suffered from the MSDs symptoms, particularly in the lower back (48.9%), shoulder (45.9%), neck (44.2%), upper back (43.8%)), and knees (43.8%). In fact, the phenomenon of work-related musculoskeletal disorders (WMSDs) augments in number in developing countries, including Indonesia. Consequently, it potentially affects health compensation costs as well as reduces productivity and life quality. Recently, many studies have been carried out to provide a basis for the multi-factor risk assessment of the development of WMSDs [3].

LUBA method is an assessment technique for postural loading on the upper body based on joint motion discomfort and maximum holding time [4],[5]. The study was conducted by [6] on Batik Cap workers using the Job Strain Index (JSI) and LUBA methods. The results showed the level of ergonomic risk in the JSI method there are 11 activities at low risk level or this job is safe and 5 activities at moderate risk level, the LUBA method is related to 5 activities in category II, and 5 activities in category III, and 6 activities in the category III, and 6 activities according to category IV. Furthermore, ACGIH HAL is a method for evaluating MSDs risk factors associated with work, especially on the hands and arms [7]. Research on ACGIH HAL was conducted by [8] of 2751 manufacturing workers. The results showed that workers exposed to higher levels of risk action for Carpal Tunnel Syndrome (CTS), but no longer increased workers' risk above the Threshold Limit Value (TLV). This shows that the current level of action may not be sufficient to protect workers. The combination of Peak Strength (PF) and Hand Activity Level (HAL) is useful for predicting the risk of CTS. This evaluation is based on an assessment of hands/arms activity and the effort level for a particular posture when doing work in a short work cycle [7]

Based on preliminary observation and data collection, the process of making batik cap involves nine stages, namely: fabric preparation, basic colouring, preparation of tools and materials, cap printing onto fabric, fabric colouring, colour locking, wax removal, fabric washing, and drying. The present study is focused on the process of cap printing in which this process requires the workers to perform 14 kinds of activity. In addition, it also requires the workers to stand up for four hours and carry a cap called cap weighing two kilograms.

This posture is repetitive motions of hands, requiring their strength and situating them at the risk of MSDs. The present study aims at investigating the effect of repetitive motions on the risk of MSDs in the upper body by using the LUBA and ACGIH HAL methods.

II. RESEARCH METHODOLOGY

In the present study, five workers in charge in the process of cap printing were involved. They are the workers in MSMEs Batik Cap 'Supriyarso', which located in Kampoeng Batik Laweyan, Surakarta City, Central Java, Indonesia. They were selected based on the process in making Batik Cap that is most vulnerable to the risk of WMSDs, particularly on hands and arms, in a relatively short work cycle. The previous observation found out that this process requires the workers to stand up for approximately four hours and carry a cap weighing approximately two kilogram. The posture must be supported by hands motions on a repetitive basis, requiring both hands' exertion and situating them in experiencing MSDs. The work-related musculoskeletal risk factors most often cited in the literature include repetition, application of excessive force [8].

A. Data Collection

The data collected are: (1) work posture data, that is body posture data when doing work; (2) cycle time data, that is time duration data used in completing one work cycle; (3) joint movement data, namely data on the types of movements that occur between joints; (4) work time data, which is to know whether cap printing repetitions are carried out near 4 hours of work; (5) data on the amount of energy usage, namely data on the intensity of the amount of labor expenditure by workers; (6) break time data, namely data on the duration of work and rest periods in one work cycle; (7) worker's heart rate data [9],[4].

B. Data Analysis using LUBA Method

Documenting the video of the cap printing process to observe the postures or activities involved in duty cycle. Listing the postures in the process, selecting them based on period required to carry out such activities and the possibility of body postural stress. The postures are selected based on tasks with the greatest cycle time and the level of stress on the bone and muscle system. Any joint motion observed in the selected postures is weighed based on the value of relative discomfort. Calculating the postural load index for joint motions using formula developed by [4],[10] as follows (equation 1):

$$\text{Postural load index} = \sum_{j=1}^{n}\sum_{i=1}^{mj} Sij \quad \dots (1)$$

Where, *j* is the joint, *n* is the number of joints involved, *i* is the joint motion, *mj* is the number of joint motions, and *Sij* is the relative discomfort score. Determining the category based on the postural load index (Table 1).

Table 1. Categorization of Postural Load Index [4]

Category	MHT	PLI	Category	Action
I	>10 min	<5	Acceptable	No corrective actions are needed.
II	5-10 min	5-10	Requires further investigation	Immediate intervention is not needed.
III	2-5 min	10-15	Requires corrective action	Redesigning workplaces or working methods
IV	<2 min	>15	Requires immediate corrective action	

Description: MHT = Maximum Holding Time, PLI =postural Load Index.

C. Data Analysis using ACGIH HAL Method

There are seven steps in processing data using the LUBA method, is: (1) identifying HAL on a scale of 0 to 10 (0 = completely idle and 10 = the greatest level of repetition imaginable, or continuous exertion); (2) determining the exertion frequency and duty cycle (% of the work cycle where force is greater than 5% of the maximum); (3) determining the value from the Borg Scale by examining the worker's heart rate; (4) characterizing the work level by linking the exertion frequency in one work cycle and determining the Normalized Peak Force (NPF). NPF is the relative level of work on a scale of 0 to 10, in which it refers to the strength of humans in the same posture to complete the task. Such a force can be measured using one of the three methods, namely Percent of Maximum Voluntary Contraction (MVC) by comparing force with population in the same posture using electromyography, Subjective Perceived Exertion (Borg Scale), and Moore Garg Observer Scale; (5) combining HAL and NPF in TLV graph. (6) evaluating the calculation results using the ACGIH-HAL TLV analysis table; (7) analyzing the TLV graph with the following conditions: (a) if the result is above the TLV line (the activity is unacceptable, redesigning workplaces is crucial to reduce the adverse effects); (b) if the result is between AL and TLV (determination of work limits, change in workplaces must be considered to reduce activity and medical supervision should be carried out); (c) if the result is below AL, the activity is acceptable.

The equation [9],[11] as follows (equation (2), (3), (4)):

Determination of exertion frequency in one cycle time is frequency $= \frac{Exertion}{one\ cycle\ time} \dots (2)$

Determination of the period in one cycle time is period $= \frac{one\ cycle\ time}{exertion} \quad \dots (3)$

Determination of total exertion in one cycle time is duty cycle =

$$\frac{Total\ one\ cycle\ time}{(Total\ one\ cycle\ time + Total\ break\ time)} \times 100\% \quad \ldots (4)$$

III. RESULTS AND DISCUSS

The five workers involved in the present study are in charge in the process of cap printing and between ages of 48 years and 60 years. Based on LUBA method, there are 14 activities while based on ACGIH HAL method, there are 13 activities to be investigated.

The activity of covering the motif is done to prevent the former motif of being covered by the newer one. Such an activity involves two postures, namely the posture of covering the motif of line 1 and the posture of covering the motif of line 2, in which the lines are distinguished based on the distance of the motive to the body of the worker. The subsequent activity is to remove the cap from the furnace. The activity of putting the cap is done to position the cap in an order or precise position, which involves the line 1 posture, line 2 posture and line 3 posture, where these lines are distinguished based on the distance of the cap placed on the body of the worker. Cap printing activity is an action taken to create a motif by attaching and pressing the cap to the cloth so that the wax will be attached to the fabric. This activity involves three postures, namely line 1 posture, line 2 posture and line 3 posture, distinguished based on the distance from the body of the worker. The activity of removing the cap is accompanied by returning it to the furnace so as it will be filled by the wax again. The activity of uncovering the motif is an activity that aims to prevent the previous motif from being covered by newer motif. Such an activity involves two postures, namely line 1 posture and line 2 posture, distinguished based on the distance of the motif from the body of the worker as specified in Table 2.

Table 2. The Process of Cap Printing with LUBA and ACGIH HAL Methods

Method	No.	Activity	Worker 1		Worker 2		Worker 3		Worker 4		Worker 5	
			Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
LUBA	1	Covering motif on first line	v	v			v	v	v	V		
	2	Covering motif on second line	v	v			v	v	v	V		
	3	Removing the cap from the furnace	v	v	v	v	v	v	v	V	v	v
	4	Putting the cap onto first line	v	v	v	v	v	v	v	V	v	v
	5	Putting the cap onto second line	v	v	v	v	v	v	v	V	v	v
	6	Putting the cap onto third line	v	v	v	v	v	v	v	V	v	v
	7	Putting the cap onto fourth line									v	v
	8	Pressing the cap on first line	v	v	v	v	v	v	v	V	v	v
	9	Pressing the cap on second line	v	v	v	v	v	v	v	V	v	v
	10	Pressing the cap on third line	v	v	v	v	v	v	v	V	v	v
	11	Pressing the cap on fourth line									v	v
	12	Replacing the cap to the furnace	v	v	v	v	v	v	v	V	v	v
	13	Uncovering motif on first line	v	v			v	v	v	v		
	14	Uncovering motif on second line	v	v			v	v	v	v		
ACGIH HAL	1	Picking the motif		v			v	v	v			
	2	Covering the motif	v				v	v	v	v		
	3	Holding the cover of motif 1		v								
	4	Removing the cap from the furnace	v		v		v		v		v	
	5	Carrying the cap 1 printing	v		v		v		v		v	
	6	Holding the cap	v	v	v		v		v		v	
	7	Pressing the cap	v		v	v	v		v		v	v
	8	Removing the cap from fabric	v		v		v		v		v	
	9	Carrying the cap 2	v		v		v		v		v	
	10	Uncovering the motif	v				v	v	v	v		
	11	Holding the cover of motif 2		v								
	12	Replacing the motif		v			v		V			
	13	Moving the fabric aside	v	v	V	v	v	v	V	v	v	v

A. Results of LUBA Method

The activity of performing printing on the line 1 was observed from three angles as demonstrated in Figure 1, from the right side for right body posture, front for sideways posture, and left side for left body posture.

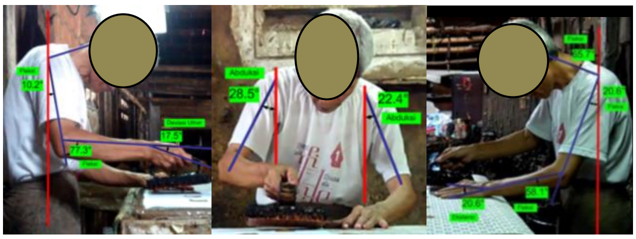

Figure 1. Activity of Cap Printing on the Line 1

Table 3 shows that in the activity of cap printing on the line 1, the postural load indexes of the worker's right hand and left hand were, respectively, 12 and 11. These values show the risk level of both hands is classified into category three with the postural load index from 10 to 15. This categorization is important to perform an evaluation through the re-designation of workplace or working method.

The difference in the postural load indexes of the right and left hands is indicated by the angle of ulnar deviation. The index of the right wrist is higher than the left wrist. Moreover, neck becomes the greatest factor in the postural load index with an index of five.

The activity of picking up the cap was observed from three angles as reflected Figure 2, from the right for observing the right posture, front for observing the side posture, and left for observing the left posture.

Table 3. The postural load index of the activity of cap printing on the line 1

Activity: Putting the cap on the Line 1	Operator: Respondent 1			Date: 19 July 2017		
Joints	Right hand			Left hand		
	Posture	Class	Value	Posture	Class	Value
Wrist	Ulnar deviation	10º-20º	3	Extension	20º-45º	2
Elbow	Flexion	45º-120º	2	Flexion	45º-120º	2
Shoulder	Flexion	0º-45º	1	Extension	0º-45º	1
	Abduction	0º-30º	1	Abduction	0-30º	1
Neck	Flexion	>45º	5	Flexion	>45º	5
Back	Neutral	0º	0	Neutral	0º	0
Postural Load Index			12			11

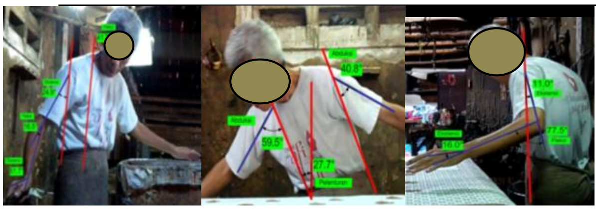

Figure 2. Activity of picking up the cap

Table 4 specifies the activity of picking up the cap as carried out by the respondent 1, in which the postural load indexes of the right and left hands are, 27 and 19, respectively. It implies the risk level of both hands can be classified into category 4 with postural load index of 15 or higher. This category of posture requires immediate consideration and corrective actions.

The difference the postural load indexes between the right hand and left hand is indicated by the angle of the wrist extension and shoulder extension. The index of the right wrist is 6 points higher compared to the left wrist, while the right shoulder abduction is three points higher compared to the left. Backs are the biggest factor in the postural load index with an index of nine.

Table 4. Activity of putting the cap

Activity: Putting the cap	Operator: Respondent 1			Date: 19 July 2017		
Joints	Right hand			Left hand		
	Posture	Class	Value	Posture	Class	Value
Wrist	Extension	>45º	7	Extension	0º-20º	1
Elbow	Flexion	0º-45º	1	Flexion	45º-120º	2
Shoulder	Flexion	20º-45º	4	Extension	0º-20º	1
	Abduction	30º-90º	3	Abduction	30º-90º	3
Neck	Flexion	20º-45º	3	Flexion	20º-45º	3
Back	Lateral flexibility	20º-30º	9	Flexion	20º-30º	9
Postural Load Index			27			19

B. Results of ACGIH HAL Method

Observation of the workers by using the ACGIH HAL method was focused on HAL of both the right and left hands. Data input used by ACGIH HAL is direct observation data with the equipment of video recorder, stopwatch and pulse meter.

Measurement of worker's heart rate was used to determine the NPF value. It was done four times, with the measurement period every one hour and starting one hour after working. Based on Table 5, the measurements showed the mean heart rate of workers was 67.75 beats per minute.

Table 5. Worker's heart rate

Measurement time	Heart rate (beats per minute)
The first hour	67
The second hour	67
The third hour	69
The fourth hour	68
Mean	67.75

Result of the right hand (Respondent 1)

Observation of the worker's right hand was conducted to determine the HAL of the workers in completing one work cycle in the process of cap printing.

Table 6. The exertion frequency of the worker's right hand

Activity	Frequency
Covering the Motif	11
Removing the Cap from the furnace	21
Carrying the Cap 1	21
Holding the Cap	21
Pressing the Cap	21
Removing the Cap from the fabric	21
Carrying the Cap 2	21
Uncovering the Motif	11
Moving the fabric aside	1
Total	149

The results obtained from the LUBA method are: identification of the activity level of workers' right hand was done by counting the number of activities that require them in using their strength or exertion for performing activities at one work cycle. The exertion frequency varies according to the number of repetitive motions carried out in one work cycle. Table 6 shows the total activities of the right hand are 149 activities.

The calculation results from respondent 1 are: (1) identification of cycle time is the required time in one work cycle is 186 s; (2) frequency in one cycle time is 0.801 exertion/s; (3) the period in one cycle time is 1.248 s/exertion; (4) total exertion in one cycle time is 180 s; (5) total break time in one work cycle is 6 s; (6) duty cycle is 96.7%.

Table 7. The HAL value of the worker's right hand

Frequency (exertion/s)	Period (s/exertion)	Duty Cycle (%) 0-20	20-40	40-60	60-80	80-100
0.125	8.0	1	1	-	-	-
0.25	4.0	2	2	3	-	-
0.5	2.0	3	4	5	5	6
1.0	1.0	4	5	5	6	7
2.0	9.5	-	5	6	7	8

The HAL value is determined by using the values of frequency, period, and duty cycle, by pointing at the frequency and period then pulling toward the specified duty cycle. Subsequently, the intersection of the two lines shows the HAL value (Table 7).

Table 7 shows that the value of frequency = 1, period = 1, and duty cycle = 80 to 100, the HAL value of the worker's right hand is 7.

The NPF value is determined based on the mean heart rate of 67.75 beats per minute or approximately 68 beats per minute. The heart rate is compared with the RPE scale, in which it is included in the value of 7.5. The RPE scale is compared to the Borg scale and a ratio scale of 0.5 is obtained. The Borg scale is the smallest scale for determining the NPF value. This scale is preferred rather than 0.3 (Table 8).

Table 8. Relationship between the Heart Rate and the Borg Scale

Heart rate	Scale	RPE	Ratio	Worker's perception
	6		0	
	7		0.3	
68	7.5	Extremely light	0.5	Extremely weak (just noticeable)
	8		1	Very weak
	9	Very light	1.5	
	10		2	Weak (light)
	11	Fairly light	2.5	
	12		3	Moderate
	13	Fairly heavy	4	
	14		5	Strong (heavy)
	15	Heavy	6	
	16		7	Very strong
	17	Very heavy	8	
	18		9	
	19	Extremely heavy	10	Extremely strong
	20		*	(almost maximum)

Based on Table 8, the Borg scale is 0.5. Subsequently, it is used to compare the values to obtain the NPF value. Table 9 shows the Borg scale is 0.5. It is classified in an extremely light category with the NPF value of 0.5. Based on the Moore-Garg Observer Scale, this value can be included in the category of barely noticeable or relaxed effort. The combination of HAL value (right hand) and NPF value, namely HAL value of 7 and NPF value of 0.5.

Results of the Left Hand (Respondent 1)

Observation of the respondents 1 left hand was done to find out the HAL of the worker in performing the process of cap printing.

Identification of the activity level of workers' left hand was done by counting the number of activities that require the worker in using their strength or exertion for performing activities at one work cycle. The exertion frequency varies according to the number of repetitive motions carried out in one work cycle.

Based on Table 10, in overall, the worker's left hand has a total of 26 postures. The calculation results from respondent 1 are: (1) identification of cycle time is the required time in one work cycle is 186 s; (2) frequency in one cycle time is 0.139 exertion/s; (3) the period in one cycle time is 7.153 s/exertion; (4) total exertion in one cycle time is 69 s; (5) total break time in one work cycle is 117 s; (6) duty cycle is 37.09%.

Table 10. The exertion frequency of the left hand (Respondent 1)

Activity	Frequency
Covering the Motif	1
Holding the cover of 1	1
Pressing the Cap	21
Holding the cover of Motif 2	1
Uncovering the Cap	1
Moving the fabric aside	1
Total	26

The HAL value is determined by using the values of frequency, period, and duty cycle, by pointing at the frequency and period then pulling toward the specified duty cycle. Subsequently, the intersection of the two lines shows the HAL value (Table 11).

Based on Table 11, the value of frequency = 0.125, period = 8, and duty cycle = 20 to 40, the HAL value of the worker's right hand is 1. The NPF value of the right hand was 0.5, therefore the NPF value of the left hand was also 0.5 since it was measured based on the worker's heart rate. The combination of the HAL value (left hand) and NPF value, namely HAL value of 1 and NPF value of 0.5.

Table 9. Relationship between the Borg scale and the NPF value [12]

%MVC	Scale	Subjective (Borg Scale)	Moore-Garg Observer Scale	NPF
	Score	Worker's perception	(Alternative Method)	
0	0	Nothing at all		0
5	0.5	Extremely weak (just noticeable)	Barely noticeable or relaxed effort	0.5
10	1	Very weak		1
20	2	Weak (light)	Noticeable or defined effort	2
30	3	Moderate		3
40	4		Obvious effort but unchanged facial expression	4
50	5	Strong (heavy)		5
60	6		Substantial effort with changed facial expression	6
70	7	Very strong		7
80	8			8
90	9		Uses shoulder or trunk for forces	9
100	10	Extremely strong (almost maximum)		10

C. The Comparison between LUBA and ACGIH HAL methods

The comparison between LUBA method and ACGIH HAL method was done using statistical test with SPSS Version 21.0. It aimed at revealing the correlation and the difference between those methods. Categorization was done to classify the final results of the observation into three risk scale classifications. It is used to equalize the level of risk scale of the two methods hence the results of these categories can be used for comparing the two methods. The provision of the risk category are as follows:

a. Category 1 = LUBA category 1 and ACGIH-HAL below AL.

b. Category 2 = LUBA category 2 and ACGIH-HAL between AL and TLV.

c.Category 3 = LUBA category 3,4 and ACGIH-HAL above TLV.

Table 11. The HAL value of the worker's left hand

Frequency	Period	Duty cycle (%)				
(exertion/s)	(s/exertion)	0-20	20-40	40-60	60-80	80-100
0.125	8.0	1	1	-	-	-
0.25	4.0	2	2	3	-	-
0.5	2.0	3	4	5	5	6
1.0	1.0	4	5	5	6	7
2.0	9.5	-	5	6	7	8

Table 12. Categorization of the risks in LUBA and ACGIH HAL Methods

Method	No	Activity	Respondent 1 Right	1 Left	2 Right	2 Left	3 Right	3 Left	4 Right	4 Left	5 Right	5 Left	Postural load index
LUBA	1	Covering motif on first line	14	15	-	-	11	13	11	8	-	-	12,0
	2	Covering motif on second line	14	11	-	-	7	8	10	10	-	-	10,0
	3	Removing the cap from the furnace	27	19	10	9	9	12	13	19	9	11	13,8
	4	Putting the cap onto first line	12	11	15	8	14	6	11	15	15	10	11,7
	5	Putting the cap onto second line	15	13	18	11	11	6	13	15	17	10	12,9
	6	Putting the cap onto third line	15	13	18	10	15	9	10	14	14	9	12,7
	7	Putting the cap onto fourth line	-	-	-	-	-	-	-	-	13	12	12,5
	8	Pressing the cap on first line	15	12	13	12	10	10	9	15	16	8	11,9
	9	Pressing the cap on second line	13	12	17	11	10	11	8	7	16	9	11,4
	10	Pressing the cap on third line	17	11	16	10	10	7	8	15	18	9	12,1
	11	Pressing the cap on fourth line	-	-	-	-	-	-	-	-	18	11	14,5
	12	Removing the cap, returning to the furnace	27	19	10	9	9	12	13	19	9	11	13,8
	13	Uncovering Motif on first line	14	15	-	-	11	13	11	10	-	-	12,3
	14	Uncovering motif on second line	14	11	-	-	7	8	10	10	-	-	10,0
	Mean Postural Load Index		16,4	13,5	14,6	10,0	10,3	9,6	10,5	13,1	14,5	10,0	-
	LUBA category		3	3	3	2	3	2	3	3	3	2	3
ACGIH HAL	1	HAL	7	1	7	2	7	1	7	1	7	2	-
	2	NPF	0,5	0,5	3	3	2	2	1	1	2	2	-
	Coordinate		(7;0,5)	(1;0,5)	(7;3)	(2;3)	7;2)	1;2)	(7;1)	(1;1)	(7;2)	(2;2)	-
	ACGIH HAL category		1	1	3	1	2	1	1	1	2	1	1

Table 12 shows the final value of LUBA in each part of the worker's body was obtained from the mean of all activities. Meanwhile, the value of ACGIH HAL was derived from coordinate risk.

The final value was classified into the risk category with the same scale. The final results of the recapitulation of risk categories is demonstrated in Table 13. This recapitulation would be the input for data test using SPSS Version 21.0. The comparison between LUBA and ACGIH HAL method will reveal the correlation and the differences of data obtained from both methods.

Table 13. Recapitulation of Risk Categories for LUBA and ACGIH Methods

Worker	LUBA		ACGIH HAL	
	Right	Left	Right	Left
1st	3	3	1	1
2nd	3	2	3	1
3rd	3	2	2	1
4th	3	3	1	1
5th	3	2	2	1

Based on Table 13, the risk categories in the right body parts tend to be higher compared to the left ones. Normality test was used to investigate whether the data is normally distributed or not, and subsequently, to classify whether it is classified into Parametric or Non Parametric data.

Table 14. Results of Shapiro-Wilk Test for Normality

Method	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
LUBA	.433	10	.000	.594	10	.000
ACGIH HAL	.416	10	.000	.650	10	.000

Table 14 shows the significance value of 0.000, or <0.05, hence the data were not normally distributed and included in the Non Parametric data.

Table 15. Results of Spearman's Rank Correlation Coefficient

			LUBA	ACGIH HAL
Spearman's rho	LUBA	Correlation Coefficient	1.000	.423
		Sig. (2-tailed)		.224
		N	10	10
	ACGIH HAL	Correlation Coefficient	.423	1.000
		Sig. (2-tailed)	.224	
		N	10	10

Correlation Test is used to find out whether LUBA and ACGIH HAL methods have a correlation in determining possible risks and to the extent of the correlation. The results of the correlation test are indicated by value Spearman's rho pada Spearman's Rank Correlation Coefficient (Table 15).

Furthermore, Table 15 reveals the correlation coefficient value of 0.423 (between 0.26 to 0.50) hence it is included in the moderate category. Fair and positive coefficient value indicates a one-way correlation, which implies both methods have similarities in identifying a higher risk of the right hand and lower risk of the left hand. The significance value was 0.224 at a significance level of > 0.05, hence the correlation is insignificant or there is no correlation.

The Mann-Whitney U test was used to assess for significant differences between the general results of LUBA and ACGIH HAL methods as well as to test the hypothesis. In testing the differences determined by the hypothesis that will be used as a reference for testing the data, the hypothesis is determined as follows: Ho = the absence of difference between the risk value of LUBA and the risk value of ACGIH HAL, and Ha = the difference between the risk value of LUBA and the risk value of ACGIH HAL.

Table 16. The results of Mann-Whitney U test

	Risk
Mann-Whitney U	9.500
Wilcoxon W	64.500
Z	-3.264
Asymp. Sig. (2-tailed)	.001
Exact Sig. [2*(1-tailed Sig.)]	.001[a]

Based on Table 16, the Asymp. Sig. (2-tailed) was 0.001 in which the significance level was <0.05, hence Ha was accepted. It implies there is a difference between the LUBA Risk Value and the ACGIH HAL Risk Value. The difference shows the risks discussed in LUBA method and ACGIH HAL method are dissimilar. Therefore, this method is feasible to identify the risks of certain postures and HAL of a task.

D. Analysis of Data Processing of LUBA and ACGIH HAL Methods

The results of data processing using LUBA and ACGIH HAL method were used to determine the prevalence of risk to the workers, the highest risky activity and the risk categories. Analysis of the results was to examine all the results of data processing from LUBA and ACGIH HAL methods in determining risk values and statistical tests on both methods. The recapitulation of the results is presented in Table 12.

Based on the results of data processing in both methods, the risks in the right parts of the body are found to be higher. It implies that the worker's right hand has a higher risk of MSDs. The results of the LUBA method have a mean risk value of 3, which indicate the process of printing requires immediate corrective action. Meanwhile, the mean risk value obtained from the ACGIH HAL method was one, implying the activity is acceptable and no corrective actions are required.

The LUBA method reveals that the greatest postural load index is on the activity of picking the cap from the furnace and returning it on the respondent 1 with a value of 27. This high postural load index was the result of the back's lateral flexibility of nine. Thus, the back is very potential to have the risk of MSDs.

The mean value obtained from ACGIH HAL method is included in category 3 as found in the 2nd respondent. Based on the results of ACGIH HAL data processing, the effect of NPF value is very significant for the high risk category as indicated by the 2nd, 3rd, and 5th respondents. Meanwhile, HAL has insignificant effect on the 1st and 4th respondentss. Yet the 2nd respondentr shows a low HAL value in the left body parts, which lowers the category. In their application, the NPF value and HAL value influence each other on the magnitude of the risk.

Essentially, the risk level obtained from LUBA method is higher compared to the level from ACGIH HAL method, which implies the risk of upper body posture is higher than the risk of HAL.

IV. CONCLUSION

1. Evaluation on the activities in the cap printing process has been done using the ACGIH HAL method. It reveals that repetitive motions influenced by work speed HAL and work fatigue NPF may pose a risk of muscle fatigue. The right hands of the workers assigned in the cap printing process are more vulnerable to such a fatigue. Meanwhile, the left hands have a lower risk. The difference is caused by the higher frequency of the right hand compared to the left hand during the process of cap printing. Hence, the burden of the right hand must be lessened as an effort to prevent muscle fatigue.
2. The working situation in the cap printing process as a stage in making Batik Cap is very risky for muscle fatigue, particularly in the postural load. It requires immediate corrective action. The analysis using LUBA method reveals that the activities in this process are high risk conditions, particularly in the activity of removing the cap from furnace, putting the cap and returning it to the furnace. It is exacerbated by the layout and model of the workplace—which is less ergonomic—hence redesignation of workplace is required. HAL in this process is quite high, especially the right hand. As recommendation, working methods should be revised and supporting tool can be utilized to reduce muscle fatigue caused by repetitive motions.
3. The LUBA and ACGIH HAL methods have no correlation yet having significant differences in risk values. Consequently, in identifying potential risks, they can support each other to reinforce the evaluation of an activity. LUBA method focuses on the posture while ACGIH HAL method at the hand activity level. The first has a higher risk value than the second method, implying the significance of posture evaluation.

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