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Effectiveness of Ergonomic Chair against Musculoskeletal Disorders in Female Batik Workers of Sragen District

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Abstract

The majority of female batik workers uses non-ergonomic chairs *(dingklik)* that pose risks of musculoskeletal disorders. This study aimed to design an ergonomic chair and evaluate its effectiveness in reducing musculoskeletal disorders among the workers. This is a quasi-experimental study (using one group pre and post-test design) on 50 female batik workers selected by quota sampling. Musculoskeletal disorders were measured among the samples before and after the use of the designed ergonomic chair which they were asked to use for two months. T-test, ANCOVA, Wilcoxon test, McNemar test and Chi Square test were used for the analysis. The study found statistical significant differences of risk factor against musculoskeletal disorders among the workers before and after their use of the designed ergonomic chair (p< 0.05); and of musculoskeletal disorders before and after using the ergonomic chair (p= 0,035). Body Mass Index (BMI) was identified as a confounding factor, and statistical significant difference of musculoskeletal disorders were also found among the workers with <25 and >25 BMI even before and after using the ergonomic chair (p=0.033 and p=0.015 respectively). By ANCOVA statistical test, after controlling BMI, another statistical difference of musculoskeletal disorders was also identified before and after using the ergonomic chair (p=0.033). It is concluded that the designed ergonomic chair is effective to reduce the risk of musculoskeletal disorders.

Abstrak

Pengaruh Pemakaian Kursi Ergonomis terhadap Gangguan Muskuloskeletal pada Pekerja Wanita Batik Tulis di Kabupaten Sragen. Sebagian besar posisi kerja pekerja batik tulis di Sragen tidak ergonomis, sehingga berisiko terjadi gangguan muskuloskeletal. Penelitian ini bertujuan untuk mendesain kursi ergonomis dan menilai efektifitas desain kursi terhadap gangguan muskuloskeletal pekerja wanita batik tulis. Jenis penelitian adalah eksperimental quasi dengan pendekatan *one group pre and posttest design*. Populasi adalah seluruh pekerja industri Batik Sragen. Teknik sampling *quota random sampling*. Sampel sebanyak 50 orang diukur tingkat risiko keparahan gangguan muskuloskeletalnya sebelum dan sesudah menggunakan kursi ergonomis. Selanjutnya, dilakukan uji *Wilcoxon test*, *McNemar test*, dan *Chi Square test.* Perbedaan tingkat risiko keparahan muskuloskeletal sebelum dan sesudah menggunakan kursi ergonomis (p< 0,05). Terdapat perbedaan keluhan muskuloskeletal sebelum dan sesudah menggunakan kursi ergonomis (p=0,035). Indeks massa tubuh teridentifikasi sebagai *confounding factor* karena terdapat hubungan yang signifikan terhadap gangguan muskuloskeletal, baik sebelum maupun sesudah menggunakan kursi ergonomis (masing-masing p=0,033 dan p=0,015). Melalui uji *Ancova*, *confounding factor* dikendalikan, diperoleh hasil uji yang tetap signifikan (p=0,033). Kursi kerja ergonomis menurunkan risiko keparahan gangguan muskuloskeletal.

Keywords: *ergonomic chair, musculoskeletal disorders*

Introduction

UNESCO has categorized Indonesian batik as an intangible cultural heritage which has been ratified through the Presidential Decree Number 78 Year 2007 on the ratification of UNESCO convention. One of the centers of batik industry in Central Java is located in Sragen, and it absorbs thousands of workers across various districts. The batik production in Sragen takes the form of *cap* (stamped), *tulis* (hand-drawn), print and *cabut* (combination of *tulis* and print) (Sragen Local Government, 2010).[1]

A health impairing risk on batik *tulis* workers stems from the monotonous sitting posture on an exceedingly low *dingklik* (short batik-crafting stool) causing them to hunch over during work. This indicates an incompatibility between the workers' anthropometric dimension and the work facility that poses the risk of musculoskeletal disorders. According to Helander (1995), a long period of hunched over posture will result in musculoskeletal disorders-related complaints regarding the joint angle.[2]

Protection for batik *tulis* workers may be conducted through approaches in ergonomics and occupational health by adjusting the size of work facility to body dimension in order for the musculoskeletal system to not be disrupted. This research aimed to design an ergonomic chair and evaluate the chair design effectiveness against musculoskeletal disorders of batik *tulis* female workers.

As a consideration to improve the chair design, the writer used Ovako Working Analysis System (OWAS) method with observations that found workers had hunched and twisted back posture (score 4), position of both arms being under shoulder height (score 1), kneeling leg position (score 6) and ten kilograms of supported weight (score 1). Furthermore, the results were combined based on OWAS value table for risk categories, and the combined postures were found to be at risk category 4.

The value resulting from OWAS was then classified based on risk categories consisting of the effect on musculoskeletal system and its corrective actions. The categories are as follow: (1) Risk 1 of normal posture without affecting the musculoskeletal system (low risk) which does not require any correctives; (2) Risk 2 of posture that potentially inflicts damage on the musculoskeletal system (medium risk) which may need corrective action; (3) Risk 3 of posture with dangerous effect on the musculoskeletal system (high risk) which requires immediate correction; and (4) Risk 4 of highly dangerous effect to the musculoskeletal system (very high risk) which requires corrective action to be carried out as soon as possible.[3,4]

Based on the OWAS value, observation results indicated the risk 4 category that requires a correction in the posture of female batik workers. In this term, the writer proposed the correction by changing the working posture from hunching over on a *dingklik* to sitting on an ergonomic chair that suits the worker's anthropometry.

Methods

The type of research is quasi-experiment through preventive intervention approach, and it used one group pre and posttest design with the research design scheme as presented in Figure 1.

The research population of 300 to 600 workers was made up of the entire female workers in the batik *tulis* division of Sragen District's batik industry. The sampling technique used was quota random sampling with its inclusion criteria defined beforehand. The criteria for inclusion comprised of workers of the female sex from batik-crafting occupation who used the working posture of sitting on a *dingklik* with the stool height under their knee level when sitting. From the population, the number of samples was determined before the random sampling was carried out for those who fulfilled the criteria. The number acquired was fifty workers. Moreover, assessment on the level of musculoskeletal disorders was conducted before and after the use of ergonomic chairs (the designed work chair). The length of time to use the ergonomic chairs was two months.

Wilcoxon statistical analysis test was used to examine the difference between workers' musculoskeletal disorders before and after using the ergonomic chairs. To test whether there were any differences between musculoskeletal disorders before and after the treatment, McNemar test was used. Meanwhile, to identify the risk factors affecting musculoskeletal disorders, Chi square test was used.

$$O_1 \longrightarrow (X) \longrightarrow O_2$$

Figure 1. Research Design Scheme

Description:
O_1 : Sample group before treatment
(X) : Treatment
O_2 : Sample group after treatment

Nordic Body Map questionnaire, which its assessment uses the four point Likert scale, was used to evaluate the musculoskeletal disorders in the workers. Every score or value has an operational definition described as follows: (1) Score 1 means that there are no disturbance/sore or any sense of pain felt by the workers (does not hurt); (2) Score 2 means that there is a minor disturbance/sore in the skeletal muscle (minor hurt); (3) Score 3 means that respondents felt a disturbance/sore or pain in the skeletal muscle (hurt); and (4) Score 4 means that respondents felt a very painful or sore disturbance in the skeletal muscle (very hurtful).[3]

Furthermore, individual total scores were calculated from the entire skeletal muscle disorder scores of the 28 observed skeletal muscles. On this four point Likert scale design, the lowest individual score is 28 and the highest score is 112. A simple guideline in determining the qualification of skeletal muscle risk level subjectivity is detailed as follows: (1) Action level 1 with individual total score of 28 to 49 has a low risk level and does not require correction; (2) Action level 2 with individual total score of 50 to 70 has a moderate risk level and may require corrective action in the future; (3) Action level 3 with individual total score of 71 to 91 has a high risk level and requires immediate corrective; and (4) Action level 4 with individual total score of 92 to 112 has a very high risk level and requires that a complete corrective action be carried out as soon as possible.[3]

Results and Discussion

Ergonomic chair design. Anthropometric measurement of 50 samples were conducted and consisted of sitting knee height, buttock-popliteal length, seat breadth and back height. Afterwards, in reference to Nordic Body Map, workers' level of musculoskeletal disorders were measured before and after using the ergonomic chairs, which were designed based on data of workers' anthropometrical measurements for the research.

The design basis utilized the dimension of sitting knee height (fifth percentile), buttock-popliteal length (fifth percentile), seat breadth (ninety-fifth percentile) and back height (ninety-fifth percentile), as well as the measurement of looseness.

Work room description. Distance between workers was less than one meter in order to save costs to make way for stove and pan procurement. One stove and pan filled with wax was shared amongst five to seven workers and limited their movement. Moreover, the workers conducted monotonous motion and a non-ergonomic working posture of a hunched over sitting for seven hours per day. This condition persisted as long as their tenures last.

Description of batik-crafting stool (*Dingklik*). *Dingklik* is used by batik *tulis* workers (the batik crafters) to sit during their work. The exceedingly low design of *dingklik* makes for a hunched over, monotonous and non-ergonomic working posture. The average dimension of *dingklik* is measured at 32.1 cm long, 25.5 cm wide and 14.4 cm high with no backrest (Figure 2).

Designed chair. Ergonomic chair for the batik workers was designed based on the anthropometric measurement data of the workers. It covers sitting knee height, buttock-popliteal length, seat breadth and back height. The data description of batik female workers' anthropometric measurement result is statistically presented in Table 1.

Based on Table 1, design of ergonomic chairs for female batik workers was made with the chair dimensions shown in Table 2. The workers need to straighten their legs in order to relax more while they work since their legs are also used to support the patterned cloth. Therefore, data on chair height was reduced by five cm, and afterwards, the dimension/measurement of the ergonomic chair was made.

Figure 2. "*Dingklik*" Stool

Table 1. Data on Workers' Anthropometric Measurement

Statistical Description	Sitting Knee Height (cm)	Buttock-Knee Length (cm)	Seat Breadth (cm)	Back Height (cm)
Minimum	31.00	30.60	29.10	30.10
Maximum	40.90	51.20	40.80	44.60
Average	35.98	42.85	35.00	39.46
Fifth Percentile	33.39	38.74	30.85	35.73
Ninety-Fifth Percentile	39.49	48.27	39.73	42.46

Table 2. Dimension of the Designed Work Chair

Chair Measurement	Percentile (%)	Size (cm)
Chair Height, based on Sitting Knee Height data	5	33.39
Chair Length, based on Buttock-Knee Length data	5	38.74
Chair Width, based on Seat Breadth data	95	39.73
Backrest Height, based on Back Height data	95	42.46

The workers' need to straighten their legs in order to be more relaxed during work since the legs are also used to support the patterned cloth. This caused the data on the sitting knee height to be reduced by five cm. Moreover, the ergonomic chair is made with the following measurement/dimension:

Work chair height = (33.39–5.0) = 28.39 cm
Work chair length = 39.74 cm
Work chair width = 39.73 cm
Backrest = 42.46 cm

Description of size comparison between *dingklik* and the designed chair. The comparison of size between *dingklik* and the designed ergonomic chair is exhibited in Table 3.

Description of sitting posture comparison before and after using the designed ergonomic chair. The description on workers' sitting posture before and after using the designed ergonomic chair is as follows:

Workers' sitting position before using the designed chair (when *dingklik* was still used): (a) *Dingklik* height was too low, and the feet were unable to relax. (b) *Dingklik* length was too short, pressuring the upper legs (thighs) and blocking blood flow. (c) *Dingklik* width was too narrow, so the buttocks were not fully covered. (d) *Dingklik* was without backrest and wearied the workers. (e) Seat cushion was made of hard material which caused pressure on blood flow in the thighs.

Workers' sitting position after using the designed chair: (a) Chair height suited the height of hollow of the knee and relaxed the leg position. (b) Chair length matched the upper leg length and the seat cushion was soft. Both released pressure on the thighs. (c) Chair width was in accordance with the seat breadth making the seat more comfortable. (d) Chair was furnished with backrest so that the back may rest and weariness was reduced. (e) Seat cushion was covered in sponge to reduce pressure on blood flow in the thighs.

This design concept was implemented from the suggestion of Wignjosoebroto (2003) in avoiding less comfortable work posture and position. Therefore, the high frequency or long period of hunching over for the workers' working posture and position should decline. This is the reason why the work station design should consider its work facilities such as work tables and chairs.[5]

Description of severity levels in musculoskeletal disorders before and after using the designed ergonomic chair. Table 4 displays the description of data on severity levels of the musculoskeletal disorders. The risk of musculoskeletal disorders showed a decline of high risk level cases from 33 cases (66%) to 6 cases (12%). On the other hand, low risk level musculoskeletal disorder cases increased from 2 cases (4%) to 23 cases (46%).

Statistical test on severity level differences in musculoskeletal disorders before and after using the ergonomic chair (Table 4). Statistical test on musculoskeletal disorder differences before and after using the ergonomic chair (Table 5).

The McNemar test results presented significant output on p=0.035 ($p<0.05$). This demonstrated the difference on workers' musculoskeletal disorders before and after using the designed ergonomic chairs.

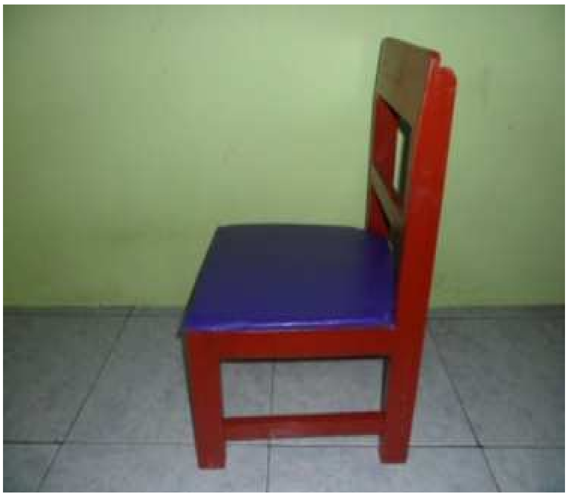

Figure 3. The Designed Chair

Table 3. Size Comparison between Dingklik and the Designed Chair

Size Dimension	*Dingklik* (cm)	Work Chair (cm)	Deviation (cm)
Height	14.4	28.39	13.99
Length	32.1	39.74	7.64
Width	25.5	38.73	13.23
Armrest	None	42.46	-
Seat Cushion	None	Sponge	-

Table 4. Wilcoxon Test Results

	Risk Level			Z	p
	High	Medium	Low		
Before	33	15	2	- 4.990	0.000
After	6	21	23		

Table 5. McNemar Test Results

	Musculoskeletal Disorders		p	Conclusion
	Disorders Found	No Disorders Found		
Before	33	17	0.035	Significant
After	6	44		

Table 6. Chi Square Test Results on Musculoskeletal Disorders before and after Using the Ergonomic Chair

Characteristic	Disorders before using Ergonomic Chair		p	Conclusion
	Found	Not Found		
Age > 40 years old	9	9	0.073	Not Significant
Age $\leq$ 40 years old	24	8		
Tenure $\geq$ 8 years	17	9	0.924	Not Significant
Tenure < 8 years	16	8		
BMI > 25 kg/m^2	16	3	0.033	Significant
BMI $\leq$ 25 kg/m^2	17	14		

The batik-crafters' musculoskeletal disorders caused by incorrect working position is in line with the statement of Suma'mur (2009) which specified that body posture and work position that are incorrect or exceeding a person's capacity will cause lower back pain (LBP). The sense of pain incurred can disturb the work.[6]

Musculoskeletal disorders in female batik-crafters resulted from the potential physiological danger coming from unfitting application of ergonomics that does not correspond to existing ergonomic norms, which cover working posture and position that satisfy ergonomic standards.

Correlation of age, tenure and body mass index (BMI) against musculoskeletal disorders before and after using the ergonomic chair (Table 6).

Test results for the difference of severity levels in the ergonomic chairs usage showed significant outcomes on p=0.000 (p<0.05). Thus, case of musculoskeletal disorders when workers were using *dingklik* was higher than when they were using the designed chair.

Test results in Table 6 exhibited that there was a risk factor affecting musculoskeletal disorders other than the usage of stool. The risk was BMI on p=0.033 (p<0.05). Meanwhile, age and tenure had no effect.

Correlation between BMI and cases of musculoskeletal disorders had also been brought up by Punnet (2004) who stated that BMI is related with musculoskeletal disorders,[7] and the same opinion was given by Samara et al. (2005).[8] Low BMI poses 2.3 times higher risk of LBP than normal BMI.

Musculoskeletal disorder differences before and after using the ergonomic chairs with controlled confounding factor. There turned out to be a confounding variable of BMI which still affected bivariate test results. Due to that, a further Repeated Ancova test was done to identify any musculoskeletal differences before and after the workers use ergonomic chairs. This was done by controlling the BMI variable, and its test results are provided in Table 7.

After the BMI variable was controlled, the test results were still at a significant point with the value of p=0.033 (p<0.05).

All the research samples were female workers from the batik *tulis* division with non-ergonomic working posture of sitting on a *dingklik.* The stool dimension was very low and forced the workers' legs to be straightened or bent. Meanwhile, the legs should have been positioned with a natural bend, and the chair height should have matched the workers' popliteal height. The *dingklik* length was also too short, and should have accommodated the length from the hollow of the knee to the sacral area. Moreover, the *dingklik* width, which should have matched seat breadth, was too narrow and limited the space for workers to move about during their work. In general, the *dingklik* design is not ergonomic, and can cause risks of musculoskeletal disorders in the form of pain in the back, neck, wrist, elbow and feet.

The illustration on severity risk levels of musculoskeletal disorders in the 50 workers before they used ergonomic chairs showed that 33 workers (66%) were in the high risk category, 15 workers (55%) in the medium risk and 2 workers (40%) in the low risk. For the high risk level, corrective action needs to be immediately carried out. The illustrative confirmed that corrections in the non-ergonomic *dingklik* need to be taken into special account since the majority of workers (66%) are at a high risk level.

Sitting for long periods of time is one the causes of frequencies in LBP with 39.7-60% occurrence rate in adults. Furthermore, Samara (2004) stated that long sitting posture and position (of more than four hours) causes tension and strain in the back muscles and ligaments that caused LBP. Moreover, the hunched over sitting position adds strain on the posterior longitudinal ligament which inflicts pain and may increase the pressure in the intervertebral disc.[9]

The exemplification of musculoskeletal disorder risk levels in the workers after their two months usage of ergonomic chairs showed that 6 workers (12%) are in the high risk level, 21 workers (42%) in the medium risk and 23 workers (46%) in the low risk level. The corrective action suggested to the workers in the medium risk level is to have the corrective action be carried out sometime in the future. Meanwhile, low risk leveled workers do not yet need corrective actions.

This showed that after using ergonomic chairs, the levels are satisfactory since there is a decline in the severity risk level of musculoskeletal disorders. Formerly, most of the risk levels fell into the category of high and medium, while afterwards, they declined to medium and low.

Correction of the work chair design was carried out in accordance with workers' anthropometric dimensions, and had them equipped with sponge seat cushion. The ergonomic chair can already now reduce the risk of direct pressure on the soft tissue in the thighs. Moreover the usage of ergonomic chairs will provide natural working posture that decreases skeletal muscle disturbance.

This illustration of research results exhibited congruence with the opinion of Nurmianto (1996) who stated that incorrect sitting posture causes back problems. Workers with incorrect sitting posture will suffer from back problems since pressure on the backbone will increase during sitting, compared to the pressure during standing up or laying down. If it is assumed that the pressure is at 100%, a tense and rigid sitting posture may cause the pressure to rise to 140%. Meanwhile, a hunched over sitting posture will increase the pressure to 190%.[10]

A research by Anjani et al. (2013) found that by improving the ergonomics of chair design for batik-crafters, Posture Evaluation Index (PEI) can decline for the design in the size range of fifth and ninety-fifth percentile.[11]

This result is in line with similar research conducted by Pratomo (2006) who found a correlation between work chair and back pain complaints of weaved sarong workers who worked with ATBM (Non Machinery Weave-Making Tool) in Pemalang, Java.[12]

The risk factors that were statistically calculated in this research consisted of age, tenure and Body Mass Index. The statistical tests showed that workers of the age above and below 40 years old are not statistically different in regards to their musculoskeletal disorders. This finding is identified for both when before they use the ergonomic chairs (χ^2=3.209; p=0.073), and after

Table 7. Test Results of Musculoskeletal Disorder Differences before and after Using the Ergonomic Chair with Controlled BMI Variable

Condition	Musculoskeletal Disorders Score	F	p
Before	70.36±6.394	4.806	0.033
After	52.54±8.888		

their usage ($p=0.075$). This research finding strengthens the previous research of Riyadina et al. (2008) who concluded that there are no differences for the age groups above and below 40 years old (OR=1.24; 95% CI: 0.94-1.64).[13]

The statistical tests showed that tenure of above and below 8 years also were not statistically different in regards to musculoskeletal disorders. The indifference happened both before the use of ergonomic chairs ($\chi^2=0.009$; $p=0.924$) and afterwards ($\chi^2=0.952$; $p=0.329$). This supports the research of Pratiwi et al. (2009) who also stated that tenure does not affect musculoskeletal disorders. However, this research categorized the tenure of above and below five years ($p=1.000$).[14]

Another statistical test on another risk factor of Body Mass Index (BMI) showed that the BMIs that are above and below 25 kg/m^2 are statistically different in regards to musculoskeletal disorders. The difference occurred both before ($\chi^2=4.529$; $p=0.033$) and after ($\chi^2=5.947$; $p=0.015$) using the ergonomic chair. This backs the research of Widodo et al. (2008) who stated that there is a quite significant correlation between corpulence and increase of lumbar curve with the value of $t=3.016$ ($t>t_{5\%}$).[15] It means that there is a correlation between the two, and the coefficient determinant was 38.07% which means that the contribution of corpulence towards an increase in lumbar curve is as much as 38.07%. This is in line with the statement of Siswono (2003) who said that the more obesed a person is, the clearer his or her motoric function disturbances and proneness to illness are.[16]

Conclusions

Size of the designed ergonomic chair for female batik *tulis* workers in Sragen District is 28.39 cm high, 39.74 cm long and 38.73 cm wide with backrest height of 42.46 cm and sponge seat cushion. Risk category levels of musculoskeletal disorders for the workers when they used *dingklik* were 66% of high risk, 30% of medium risk and 4% of low risk.

The risk category of musculoskeletal disorders in the workers after using the ergonomic chair for 2 months showed a high risk level of 12%, medium risk of 42% and low risk of 46%. There were differences in the risk severity level of musculoskeletal disorders before and after using ergonomic chair ($p<0.05$); and in musculoskeletal disorders before and after using ergonomic chair ($p<0.05$). An influential risk factor towards musculoskeletal disorders was Body Mass Index ($p<0.05$).

To reduce musculoskeletal disorders, batik *tulis* workers should use ergonomic work chair. Moreover, there should be a program to "idealize" the workers' weight, for example, regular exercise, dieting and other efforts, as well as occupational health coaching conducted by related governmental agencies.

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