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Ergonomic Chair Design as a Solution to Musculoskeletal Disorders among Traditional Cobblers: An Anthropometric Study

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ABSTRACT

This study was undertaken with the aim of engineering an ergonomic chair tailored specifically for cobblers in the Malang Regency, taking into account anthropometric measurements, the Nordic body map, and the Rapid Upper Limb Assessment method. Musculoskeletal disorders, often resulting from prolonged sitting and incorrect posture, represent significant occupational hazards for them. To mitigate these health risks, the study employed the analysis of Nordic body maps to quantify complaints based on body points, and determined anthropometric dimensions to guide the design of ergonomically correct chairs. The aspiration is that the findings of this study will diminish the prevalence of musculoskeletal disorders, while enhancing the productivity and work quality of cobblers. Cobblers are particularly susceptible to musculoskeletal disorders in the waist and left calf areas, along with the back, hips, right thigh, right calf, left foot, and right foot. Insights gleaned from the Nordic body maps analysis and Rapid Upper Limb Assessment method demonstrated the need for modifications to the traditional cobbler chair to reduce these risks. Consequently, an innovative ergonomic chair was designed, incorporating anthropometric dimensions and several distinctive features, including an adjustable tilt angle on the backrest, a height-adjustable seat base, and a seat base that conforms to the load conditions of the buttocks and thighs.

1. INTRODUCTION

The development of the creative industry cannot be avoided. The need for a product, especially conventional services, is excellent for users. One of them is the cobblers service which is dominantly found on the roadside and traditional markets, especially Malang, East Java. Cobblers services carry out activities with conventional work steps. One of them is sewing shoe sole components using a sole needle, brown, white or black sole thread. The cobbler service activity also requires a simple seat. The dimensions of the seat against the posture of the shoe sole tailor are not in accordance with ergonomics. Ergonomics has a perspective that includes human factors, anthropometry, body attitudes during work and work organization. Ergonomics has a role to plan better work techniques and reduce the prevalence of cases of musculosceletal disorders.

Cobblers service activities start at 08.00 to 18.00 WIB. From these activities, in a day, at least 3 pairs of shoes are sewn and at most 15 pairs of shoes. Each pair of shoes requires an interval time of 15 minutes to 40 minutes. This means that if you use the parameter of 15 pairs of shoes multiplied by 40 minutes, it can reach 600 minutes. This means that it can take up to 10 hours per day. This is the case raised in this research. During 600 minutes, shoe sole sewing workers spend time sitting. The existing condition while sitting is that the soles of the feet experience tiptoeing. This is because the height of the chair used is not in accordance with the dimensions of the cobblers. Not only that, the condition of bending forward often occurs during sewing a pair of shoes. Thus, the back feels pain and tingling followed by the hips and waist gradually also being attacked by pain and tingling. The condition is exacerbated by flat seating. This can cause tingling if when sewing is not balanced by standing for approximately 5 minutes [1]. During the observation of each shoe sole sewing worker, the complaints that occur are the calf and waist areas. The cause of the calf area is that when the feet tiptoe the calf muscles will experience tension and contraction. While the waist area is due to posture bending forward. The tension and contraction of the calf muscles and slouching become serious problems. The strategic step achieved requires designing a chair that is used during sewing.

Research on designing a chair that meets anthropometry according to the reference of Nordic body maps and Rapid Upper Limb Assessment Cobblers is very important. The reason is, this work requires sitting for a long time and improper posture can cause pain and tingling in various parts of the body, such as the waist and calves. Therefore, this research is considered urgent to address the health and productivity issues of shoe sole sewing workers and improve the quality of their work. In addition, a good chair product can provide comfort for workers and increase production efficiency, so it is important to develop it. Interventions that can be done are analyzing Nordic body maps to manage the level of complaints based on body points. determining anthropometric dimensions in designing cobblers chair facilities [2, 3].

This research aims to create an ergonomic chair for cobblers by considering anthropometric measurements and Nordic body maps as well as the Rapid Upper Limb Assessment method. So that it has the opportunity to reduce the risk of musculoskeletal disorders faced by cobblers while working. With a chair designed in accordance with proper ergonomics, it is hoped that cobblers can work more effectively and efficiently, and avoid the risk of musculoskeletal disorders in their bodies.

The scope of the study targeted the population of Cobblers in Malang Regency as research subjects, with sample selection conducted through purposive random sampling, with the inclusion of ages between 30-70 years. In this study, there were 20 respondents who met the inclusion criteria and became research subjects.

2. METHOD

The research design using case study-based quantitative was chosen because this method provides an opportunity to obtain numerical data that can be clearly measured and usually provides results that can be analyzed statistically. In addition, by using the case study method, researchers can explore and study cases in detail to understand the problem or phenomenon under study, so as to provide specific and detailed research results. This is especially useful in research on body posture and Nordic body maps in Cobblers, where case studies can provide in-depth information about body posture problems in this job and provide an accurate description of the Nordic body maps produced by workers. The case study is located in Malang district. The research object is the shoe sole sewing service. The research time starts from July 10, 2022 to September 22, 2022.

The study population included cobblers in Malang district. The research sampling used purposive random sampling with the inclusion of age>30 years and not more than 70 years. There were 20 respondents who met the inclusion of this study.

Primary data includes posture measurements when shoe solvers are sewing and providing Nordic body maps. While secondary data includes research references sourced from international and national reputable journals. In addition, secondary data uses supporting books and research steps related to the study of Rapid Upper Limb Assessment-anthropometry integration [2, 4, 5].

Distribute the Nordic body maps questionnaire to respondents to fill in complaints during sewing shoe soles. Measuring body posture using the RULA method:

$$\text{Group A=upper arm + forearm + wrist + group A score + workload received} \quad (1)$$

$$\text{Group B =neck + spine + legs + group score assessment A + acceptable workload} \quad (2)$$

$$\text{Grand RULA=}\sum\text{Group} \quad (3)$$

Anthropometric measurements using the 5th percentile, 50th percentile, and 95th percentile.

Determining the value of data adequacy test, uniformity test and tabulation of percentile values.

Determining the value of Nordic body maps, RULA scores and Asia Pacific reference body mass index [6], normal BMI interval 18.5-24.9 and overweight interval 23.0-24.9 then modified by assessing BMI<22.9 as not obese and BMI>23.0 as obese in respondents in reference to ergonomic chair design.

3. RESULT AND DISCUSSION

Characteristics of Respondents

Based on descriptive statistical analysis, it can be stated that the dominant service age of Cobblers is 51-60 years with experience>26 years with male sex. This statement shows that the respondents used as saturated sampling are indeed men who dominate. In addition, productive age<40 shows the least number of other intervals and the least experience is the interval of 16-20 years.

Nordic Body Maps

Analysis of Nordic body maps, which shows the 1st rank for the no sick criteria is the left upper arm and left forearm with a percentage of 46.67%, while the sick criteria are waist and left calf pain with a percentage of 50%. While the next no sick criteria include the left upper arm, right forearm and right ankle with a percentage of 43.3%. While the criteria for sick with coverage of the back, hips, right thigh, right calf, left leg and right leg 40.0%.

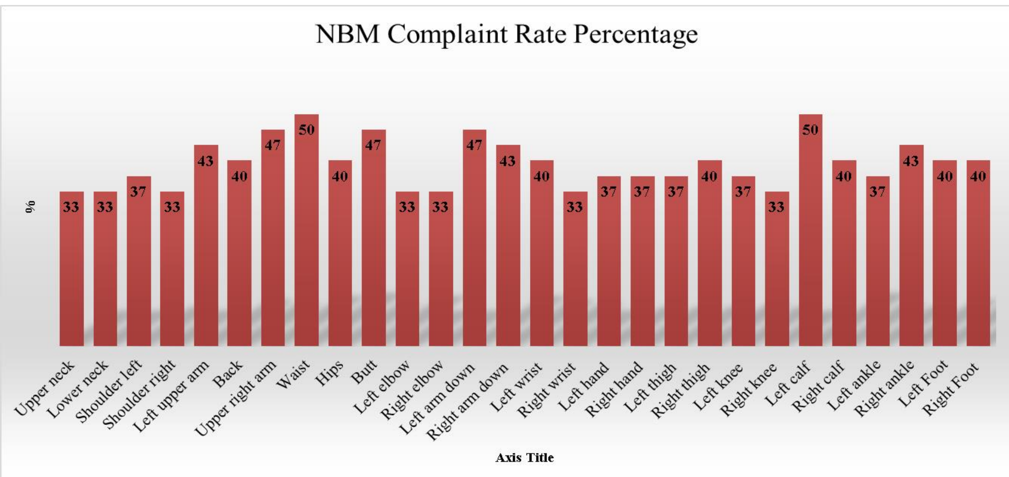


Figure 1. Complaint rate of musculoskeletal disorders (MSDs) cobblers

Figure 1, visualization of Musculoskeletal Disorders (MSDs) Cobblers complaints with the highest pain complaint rate of 50%. The findings of Hutabarat [6], Andriani et al. [7], Szczygieł et al. [8], and Zein et al. [9] proved that work activity in sitting conditions has a high level of musculosceletal disorders due to muscle tension. It is mentioned that the need for interlude activities such as rest by standing to straighten the condition of the back [10]. There was an intervention by designing a chair design to reduce muscle complaints [2, 9].

Rapid Upper Limb Assesment

Based on Figure 2 and Figure 3 the 15th respondent having the highest risk with the number of respondents of 11 samples showing a percentage of 55.0% with a ranking of 1. Rank 2 with an interval score of 5 – 6 is 8 samples with a percentage of 40.0% and ranking 3 is 1 sample with a percentage of 50.0%.

Figure 2. Sample 15th

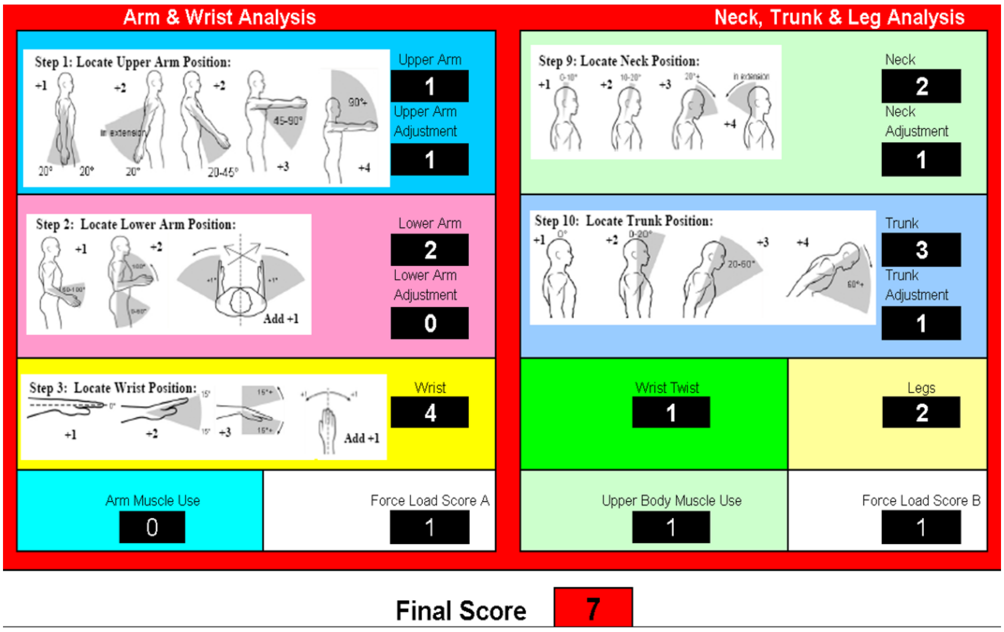


Figure 3. RULA score respondent 15 lynn McAtamney and E. nigel corlett sheet
Note: Height: 184 cm; Height category: tall; Weight: 83 kg; Weight category: BMI Fat

Table 1. RULA risk ranking

Score	Risk Level	Number of Respondents	%	Rank
1-2	Neglibible risk, no action required	0	0.0%	4
3-4	low risk, change may be needed	1	5.0%	3
5-6	medium risk, further investigation, change soon	8	40.0%	2
7+	very high risk, implement change now	11	55.0%	1
Count		20	100.0%	

Table 1, Score of Rapid Upper Limb Assessment with a dominant score of 7 as very high risk, implement change now. However, within a period of > 6 months, it will become a risk factor with more complaints than the Nordic Body Maps analysis that has been analyzed [11]. In the work of Cobblerss, workers are dominant in a forward bent position and their feet are leaning on the chair "pot" with their feet at an angle of < 30^0. Therefore, anthropometric measurements after Nordic body maps are considered to reduce tingling in the legs and thighs [12, 13].

Anthropometry

Table 2. Anthropometric percentile

Body Dimension	Percentile Value		
	5th	50th	95th
Popliteal Height (POH)	**44**	45	48
Popliteal Length (POL)	54	**58**	60
Hip Width (HW)	35	37.5	**40**
Sitting Backrest Height (SBH)	38	**40.5**	43
Sitting Shoulder Height (SSH)	59	**60**	61
Sitting Elbow Height (SEH)	18	**20**	21

Source: data processing, 2022

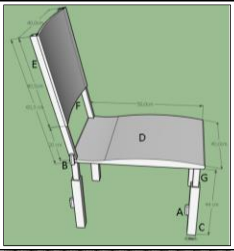
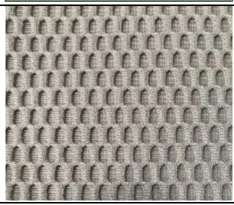
The decisions used by the researchers and the approval of respondents include POH dimensions of 44 cm, POL dimensions of 58 cm, HW dimensions of 40 cm, SBH dimensions of 40.5 cm, SSH dimensions of 60 cm and SEH dimensions of 20 cm. Table 2, apart from being the basis for designing chairs, is also a step towards providing sustainable work facilities to answer the findings of Velasco et al. [14], Micheletti Cremasco et al. [15], Setiawan et al. [16], and Emmaty and Panicker [17].

Prototype Design

Table 3, specification of chair design for Cobblers services by enhancing the role of excellence. The A-code thread function gives the Cobblers service the freedom to adjust the height and low of the seat base as a plus. This plus with a maximum height of 44 cm. Specification analysis for codes C, E and G refers to hollow iron materials. Codes D and F refer to teak wood materials. There is a thread on the backrest (B) to adjust the angle of inclination of the backrest to reduce muscle tension during work.

Figure 4, design of a corrugated seating base at code 1 for the buttocks section by reducing the dimensions by 1.4 cm. Code 2 is wave-shaped for the lower thigh by increasing the dimensions by 1.4 cm. This finding is useful for providing a level of ergonomics during sitting. This is because the position of the buttocks will be lower than the thighs. The findings in modeling a corrugated sitting device are a way of reducing tingling levels. The tingling level found by Dianat and Salimi [18], due to the position of the buttocks and thighs parallel when sitting. Therefore, the support of a corrugated seating base as a solution in this design.

Table 3. Prototype specification

	Priority: A=Threads to increase and decrease the height of the tool seat B=thread to change backrest angle
	Material Plan: C=hollow iron 4 × 4 D=teak wood mesh coated "9" E=hollow iron 3 × 3 F=teak wood mesh coated "9" G=hollow iron 3 × 3 Mesh coated "9"

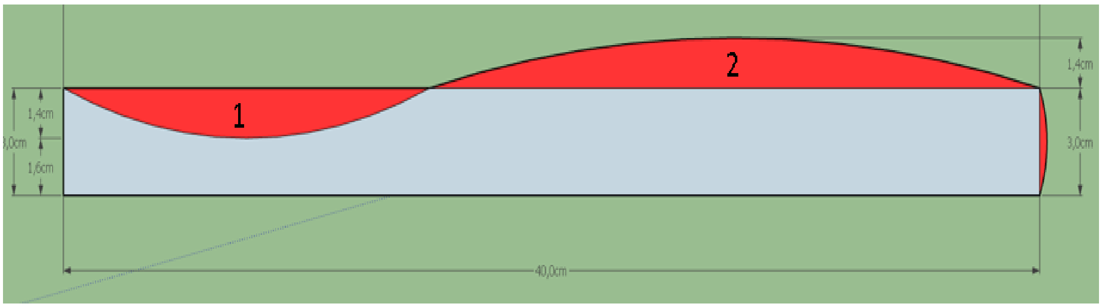


Figure 4. Seating mattress visualization

Future Discussions and Ideas

The 50% dominant MSD complaint states that it has been successful when compared to the findings of Andriani [7] and Velasco et al. [14]. This success is because the service duration of the Cobblers does not reach 40 minutes per pair of shoes. However, activities that are classified as static also provide conditions that cause tingling, especially the waist area up and abdomen down and affect body organs for a long time if not balanced with dynamic movements and consumption of mineral water once every 15 minutes.

These findings answer Mazaheri and Rose [19], that the development of the muscle complaint system is expected to decrease from that 6-month period. Activities carried out by pre-testing for the last 6 months, the last 1 month, and the last 1 week. This study also answers the findings of Velasco et al. [14] and Wibowo et al. [20] namely reducing muscle complaints requires work facilities, namely the chair design that we have designed using the integration of Nordic body maps, RULA, anthropometry and visualization of chair products with their dimensions and advantages.

4. CONCLUSIONS

The conclusions that have been reached based on the findings are (1) the highest percentage of Nordic body maps is 50% in the waist and left calf areas, 40% percentage in the back, hips, right thigh, right calf, left foot and right foot areas. (2) the dominant Rapid Upper Limb Assessment score is 7+ with a very high risk level, implement change now with a percentage of 55.0% which occupies the 1st ranking position of 11 respondents. (3) the dimensions of the selected chair product design according to anthropometry include Popliteal Height (TPO) dimension 44 cm, Popliteal Length (PPO) dimension 58 cm, Hip Width (LP) dimension 40 cm, Seat Back Height (TSD) dimension 40.5 cm, Sitting Shoulder Height (TBD) dimension 60 cm and Sitting Elbow Height (TSD) dimension 20 cm with the advantages of the design there is a tilt angle thread on the backrest, adjusting the height of the sitting mat and designing a sitting mat that adapts to the conditions of the buttock load and thigh load by making a 1.4 cm downward curve for the buttocks and a 1.4 upward curve for the thighs.

It is important for future research to consider more than 20 respondents because with a larger number of respondents, the research results obtained will be more accurate and reliable. This is due to the greater variation in the sample collected, so that it will be more representative of the actual population. In addition, with a larger number of respondents, it can increase the level of external validity of the research, namely the ability to generalize the research results to a wider population. When using a small number of respondents, such as less than 20 people, sampling errors can occur which result in the research results not representing the population as a whole. Therefore, to avoid bias and ensure more valid research results, increasing the number of respondents in future studies is highly recommended.

The suggestions given for further researchers are to realize the achievement of the implications set out in this article and for readers and the general public can be used as a reference for a chair product design and a reference for determining body dimensions in anthropometric measurements, and Rapid Upper Limb Assessment.

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