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Ergonomic Finishing Workstation Design to Resolve Musculoskeletal Disorders Complaints of Workers in MSEs of Silver Jewelry Handicraft

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ABSTRACT

The silver industry in Indonesia has the advantage of a long history, most of the craftsmen run it from generation to generation, among others, by traditional methods, especially for carving (handmade). SE SILVER 999 is a gold and silver craft business in Malang. These MSE produces quality jewelry products with unique designs that are made manually or handmade. In the production process, before the jewelry at these MSE is ready to be displayed, the product needs to go through a finishing work station, it's because in the process of flattening at the bending work station, and in the assembly process, the jewelry is still rough in texture and pale. So that every product produced needs to pass through the finishing work station. However, the finishing work station at these MSE has not met the ergonomics aspects, in terms of the height of the polishing table, the absence of a front cover, the lack of lighting and the location of the polishing wheel point. Based on these problems, the author aims to make a design of finishing workstation with an ergonomic and safe polishing machine box for MSE SILVER 999 using the REBA method.

Key words : Ergonomic, Musculoskeletal Disorders, Finishing Workstation, Silver Jewelry Handicraft.

1. INTRODUCTION

The silver jewelry industry in Indonesia has a long history and abundant raw materials. In general, craftsmen run this industry from generation to generation in the form of MSEs, using expertise and cultural heritage in the method, design and process of making handmade. In Malang, with the locals marketizing different kinds of handicraft product themselves, it in fact eases the tourists to find handicraft products as souvenirs typical from Malang [1].

In the production process, before the jewelry at MSE SILVER 999 is ready to be displayed, the product needs to go through a finishing work station, it's because in the process of flattening at the bending work station, and in the assembly process, the jewelry is still rough in texture and pale. So that, every product that is produced needs to pass through a finishing work station to smooth the texture of the product and make the jewelry product more shiny, so that the product becomes more worthy of sale.

Figure 1: Finishing Workstation [2]
(*Source: Researcher's Documentation*)

However, the finishing work station at MSE SILVER 999 as shown in Figure 1 has not met the ergonomics aspects, in terms of the height of the polishing table, the absence of a cover for the front section, the lack of lighting and the location of the polishing wheel point on both sides, making the crafter has to turn his body when changing the polishing process from large to small polishing wheel points.

Based on the interview with the owner and the crafter of MSE SILVER 999, it shows that the finishing work station produces dust and small particles that lead to workers when it is operated, the dust should be collected in one place because the polished dust contains gold and silver.

According to the history of MSE SILVER 999, there was once a work accident on a crafter while polishing which resulted in permanent disability in the worker's eyes due to small particles that hit the eyes during the finishing process. That is because at these MSE has not got an Standard Operating Procedure (SOP) in carrying out the jewelry production process, especially the finishing work station. The worker posture at the finishing workstation is shown in Figure 2.

Figure 2: Worker Posture at the Finishing Workstation [3] (*Source: Researcher's Documentation*)

Based on these problems, the author aims to make a design of finishing workstation with an ergonomic and safe polishing machine box for MSE SILVER 999.

2. MATERIALS AND METHODS

2.1 Product Design

Designing is a process that aims to compile and improve particular system, both physical and non-physical for the future by utilizing existing information. Product design can be defined as a process of drafting the concept of a product, both new products and product development in the form of technical drawings to meet what customers want (market pull) or to take advantage of innovation (technology push). Within this frame of reference, includes engineering design (mechanical, electrical, software, etc.) and industrial design (aesthetic, ergonomic, user interface) [4].

Innovative products can be defined as products made based on a new idea. These new ideas can be obtained from various sources in the form of market feedback or from five other aspects, namely Product Trends, Intellectual Property, Ergonomics, SHE (Safety, Health, Environment), and new technologies [5].

The activity of making handicraft products can be categorized as activities that have repetitive movements [6], varying loads, translational movements, rotations, combinations of translation and rotation with a static sitting position [7] and uncomfortable positions so that they are prone to fatigue in the limbs [8].

2.2 Ergonomics

Ergonomics is a scientific discipline that studies humans in relation to work. This arises because humans have limited capabilities when dealing with the work system environment in the form of hardware (work machines and equipment), software (work methods, systems, and procedures) [9].

Ergonomics is a knowledge, art and application of technology to adapt or balance all facilities used both in activities and rest with human abilities and limitations both physically and mentally so that the overall quality of life becomes better [10].

In its development, Ergonomics is classified into four areas of investigation, namely the appearance, physical strength of humans, the size of the workplace, and the work environment [11].

2.3 Anthropometry

The term anthropometry comes from the word "ANTHRO" which means human and "METRI" which means measure. Definitively, Anthropometry is a numerical collection that deals with the physical characteristics of the human body, size, shape and strength as well as the application of these data for handling design problems. The application of this anthropometric data will be carried out if the mean and standard deviation values of a normal distribution are available [12].

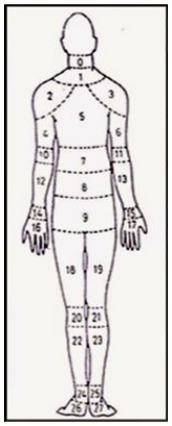
Anthropometry is a study that is concerned in measuring human body dimensions which basically have different shapes, sizes and weights from one to another. Anthropometry is widely used as an ergonomic consideration in the process products design and work systems that require human interaction [13].

Through the workers anthropometric approach and human limitations in their interaction with the working environment, ergonomic workstation design and worker performance influentially determine work productivity [14].

2.4 Nordic Body Map

Nordic Body Map as shown in Table 1 is one of the tools/methods to measure the muscle pain of the workers. The Nordic Body Map questionnaire is a form of ergonomics checklist questionnaire. With the Nordic Body Map, it is possible to identify and provide an assessment of the pain complaints experienced. This questionnaire can be done by asking respondents to fill it out [15].

Table 1: Nordic Body Map



Number	Type of Complaint	Responden	
		Pain	Painless
0	Pain in the upper neck		
1	Pain in the lower neck		
2	Pain in left shoulder		
3	Pain in right shoulder		
4	Pain in left upper arm		
5	Back pain		
6	Pain in right upper arm		
7	Waist pain		
8	Lower waist pain		
9	Pain in the ass		
10	Pain in left elbow		
11	Pain in right elbow		
12	Pain in left lower arm		
13	Pain in right lower arm		
14	Pain in left wrist		
15	Pain in right wrist		
16	Pain in left palm		
17	Pain in right palm		
18	Pain in left thigh		
19	Pain in right thigh		
20	Pain in left knee		
21	Pain in right knee		
22	Pain in left calf		
23	Pain in right calf		
24	Pain in left ankle		
25	Pain in right ankle		
26	Pain in left foot		
27	Pain in right foot		

2.5 Rapid Entire Body Assessment (REBA)

REBA aims to provide an assessment of body postures that can cause musculoskeletal related disorders. The data collected is based on data on the working posture of the pressure/load used, the type of movement or action, repetition and position of the hand when in contact with the object [16]. The REBA worksheet is shown in Figure 3.

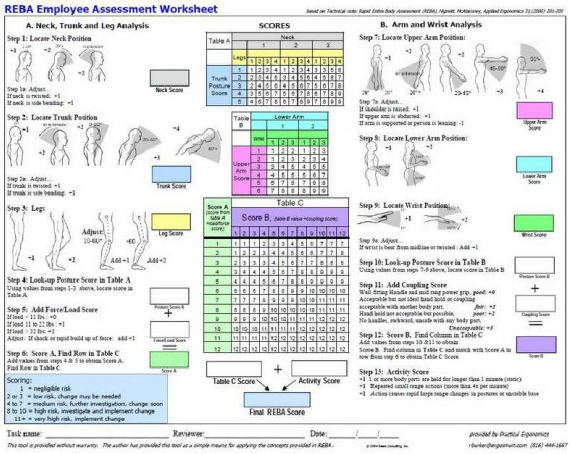


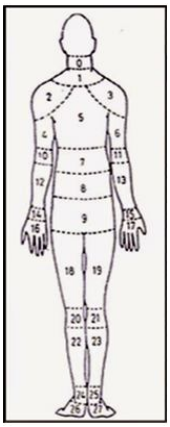
Figure 3: REBA Worksheet

3. RESULTS AND DISCUSSION

3.1 Nordic Body Map Data Processing

In Table 2, it is known that 59% of the respondent's limbs feel sick and have a risk of injury and 41% of the respondent's limbs feel no pain. The parts that have a risk of injury to the muscles are the upper neck, lower neck, left shoulder, right shoulder, waist, below the waist, buttocks, left wrist, right wrist, left hand, and right hand.

Table 2: Nordic Body Map Questionnaire at the Finishing Workstation



Number	Type of Complaint	Finishing Workstation	
		Pain	Painless
0	Pain in the upper neck	2	0
1	Pain in the lower neck	2	0
2	Pain in left shoulder	2	0
3	Pain in right shoulder	2	0
4	Pain in left upper arm	0	2
5	Back pain	2	0
6	Pain in right upper arm	0	2
7	Waist pain	2	0
8	Lower waist pain	2	0
9	Pain in the ass	2	0
10	Pain in left elbow	0	2
11	Pain in right elbow	0	2
12	Pain in left lower arm	1	1
13	Pain in right lower arm	1	1
14	Pain in left wrist	2	0
15	Pain in right wrist	2	0
16	Pain in left palm	2	0
17	Pain in right palm	2	0
18	Pain in left thigh	1	1
19	Pain in right thigh	0	2
20	Pain in left knee	1	1
21	Pain in right knee	1	1
22	Pain in left calf	1	1
23	Pain in right calf	1	1
24	Pain in left ankle	0	2
25	Pain in right ankle	0	2
26	Pain in left foot	1	1
27	Pain in right foot	1	1
	Total	33	23
	Percentage	59%	41%

After determining the parts of the muscles which are at risk of injury then scoring is carried out towards the respondents, this is carried out so that MSE SILVER 999 can find out what steps to take next.

Table 3: Risk Level Score of Nordic Body Map

Scale	Total Score	Risk Level	Corrective Action
1	1 to 14	Low	No corrective action required
2	15 to 28	Medium	Action may be required later
3	29 to 42	High	Immediate action needed
4	43 to 56	Very High	Comprehensive action is needed as soon as possible

From the results of the scoring carried out in Table 3, it is obtained a score of 33, meaning that the level of risk that will occur is on a "high" scale. So that the corrective action that needs to be taken by MSE SILVER 999 is "immediate action is needed".

Description of the 1st crafter activities is shown in Table 4. Description of the 2nd crafter activities is shown in Table 5.

Table 4: 1st Crafter Activities

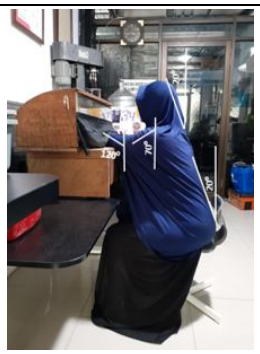
1st Crafter	Description
	1. The neck is bent at an angle of 20° 2. Back bent at an angle of 20° 3. The position of the two legs supporting the body 4. The position of the upper arm raised to form an angle of 70° 5. The position of the forearm to form an angle of 100° 6. Wrist doing circular motion

Table 5: 2nd Crafter Activities

2nd Crafter	Description
	1. The neck is bent at an angle of 10° 2. Back bent at an angle of 5° 3. The position of the two legs supporting the body 4. The position of the upper arm hanging to form an angle of 50° 5. The position of the forearm to form an angle of 125° 6. Wrist doing circular motion

Table 6: Activity Sheet of 1st Crafter

Step	Body Segment	Description	Score
1	Neck	Neck leans forward at an angle of 20° (Score +2) Neck twist left and right (Score +1)	3
2	Back	Back leans forward at an angle of 20° (Score +2) Back twist left and right (Score +1)	3
3	Legs	In a sitting position the legs still support the body	-1
4		Score A	5
5	Object Load	The weight of the object being held	6
6		Total	11
7	Upper Arm	Upper arm inclined to form an angle of 70° (Score +3) Shoulders raised (Score +1) Arm leaning (Score -1)	3
8	Forearm	Forearm bent at an angle of 100°	-1
9	Wrist	Wrist forms an angle of 20° (Score +2) Wrist rotates (Score +1)	3
10		Score B	5
11	Handle	Holding object load	3
12		Total	8
13	Body Activity	Body part held for more than one minute	1
14		Score C	12
15		REBA Score	13

Table 7: Activity Sheet of 2nd Crafter

Step	Body Segment	Description	Score
1	Neck	Neck leans forward at an angle of 10° (Score +1) Neck twist left and right (Score +1)	2
2	Back	Back leans forward at an angle of 20° (Score +2) Back twist left and right (Score +1)	3
3	Legs	In a sitting position the legs still support the body	-1
4		Score A	4
5	Object Load	The weight of the object being held	5
6		Total	9
7	Upper Arm	Upper arm inclined to form an angle of 50° (Score +3) Shoulders raised (Scor +1) Arm leaning (Score -1)	3
8	Forearm	Forearm bent at an angle of 125°	-1
9	Wrist	Wrist forms an angle of 20° (Score +2) Wrist rotates (Score +1)	3
10		Score B	5
11	Handle	Holding object load	3
12		Total	8
13	Body Activity	Body part held for more than one minute	1
14		Score C	11
15		REBA Score	12

Table 8: Risk Level Score at the Finishing Workstation

REBA Score	Risk Level	Corrective Action
1	Ignored	Doesn't matter
2 to 3	Low	Need a change in work posture
4 to 7	Medium	Further investigation and changes are needed later
8 to 10	High	An investigation must be carried out immediately for implementation in the form of changes in work posture or work environment (on the spot)
11 to 15	Very High	Must be replaced immediately in the job application (at that moment)

Based on the results of the score of 1st crafter with a value of 13 (Table 6) and the score of 2nd crafter with a value of 12 (Table 7), the resulting score is at the "very high" level, so MSE SILVER 999 needs to take an action to immediately replace in the application (Table 8).

3.2 Anthropometric Data Percentile

The calculation process is carried out using computer assistance along with Microsoft Excel software. The percentiles of anthropometric data used in designing the finishing work station design along with safety facilities (polishing machine box) are as shown in Table 9.

Table 9: Anthropometric Data Percentile

Number	Dimension	Percentile		
		P5	P50	P95
1	Thumb reach forward	65	66	67
2	Shoulder width	41	42	43
3	Knee height	42	49	56
4	Shoulder height	55	60	64
5	Elbow height	24	27	30
6	Palm width	88	98	108

3.3 Anthropometric Data of Polishing Machine Box

The polishing machine box is an additional facility designed to increase the comfort and safety of the crafters. During designing, the polishing machine box is designed using an anthropometric approach and is adjusted to the dimension of the polishing machine and work station that has been produced from the Applied Research of Industrial Engineering, University of Merdeka Malang.

3.4 Polishing Machine Box Length

The body dimension used in determining the length of the box is shoulder width using the percentile of Indonesian crafters (50%) + allowance.

Therefore, the length of the net box = 42 cm + 1 cm = 43 cm (Figure 4).

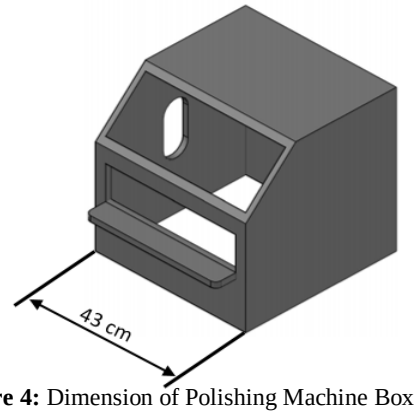


Figure 4: Dimension of Polishing Machine Box Length

3.5 Polishing Machine Box Width

The body dimension used in determining the width of the box is half of the thumb tip reach using the crafter's percentile (50%) + allowance.

Therefore, the net box width = (66 cm : 2) + 2 cm = 35 cm (Figure 5).

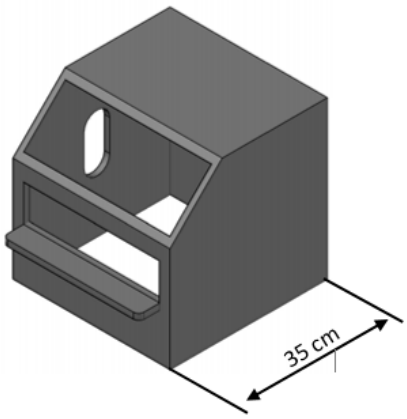


Figure 5: Dimension of Polishing Machine Box Width

3.6 Polishing Machine Box Height

The body dimension used in determining the height of the box is shoulder height (mid shoulder height sitting) – elbow height (elbow rest height) using the crafter's percentile (50%) + allowance.

Therefore, the height of the box = (60 cm – 27 cm) + 2 cm = 35 cm (Figure 6).

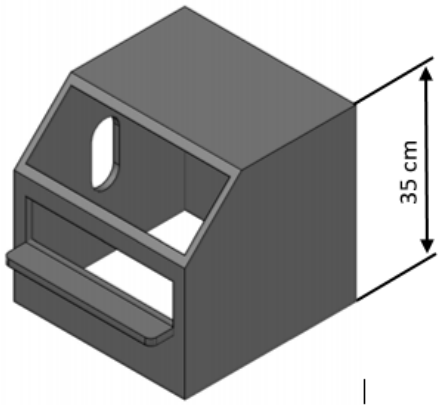


Figure 6: Dimension of Polishing Machine Box Height

3.7 Hand Hole in Polishing Machine Box

The body dimension used in determining the hand holes on the box is the width of the hands using the percentile of Indonesians (95%) + allowance.

Therefore, the hand hole height = 11 cm + 4 cm = 15 cm (Figure 7).

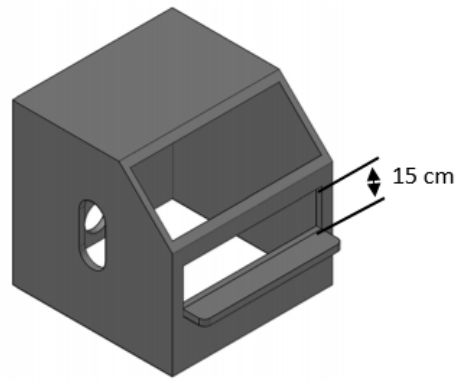


Figure 7: Dimension of Hand Hole

3.8 Design of Finishing Workstation

After using the REBA method, it shows that the risk level score is very high for both crafters, so it is necessary to take an action to immediately replace in the application of work. Therefore, it is necessary to propose a finishing work station design in the form of a table height, as well as a polishing machine box facility to reduce the risk of injury to the body and make the work position more ergonomic and safe.

Through anthropometric measurements of the crafter's body, it is possible to propose a new finishing work station design with a polishing machine located outside the left side of the polishing box. While the polishing box is on the right side of the workbench as shown in Figure 8.

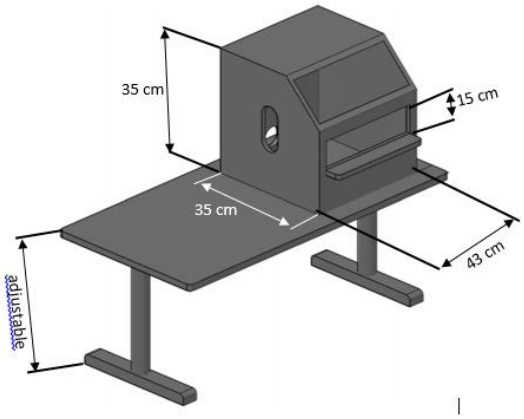


Figure 8: Design of Finishing Workstation

4. CONCLUSION

Based on the calculations and analysis of the Nordic Body Map questionnaire for workers in MSE SILVER 999, can be categorized on a "high" scale. So that the corrective action that needs to be taken by MSE SILVER 999 is "immediate action is needed". Reviewing the calculations and analysis using the REBA method, it can be categorized at the "very high" level, so MSE SILVER 999 need to take an action to immediately change in their job application.

Ergonomic finishing workstation design using anthropometric dimension at MSE SILVER 999 as follows:

1. The dimension of the finishing workstation table has adjustable height.
2. The dimension of the polishing machine box is 35 cm height, 35 cm width, 43 cm length and the hand hole height is 15 cm.

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