RESEARCH ARTICLE | DECEMBER 07 2023

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AIP Conf. Proc. 2680, 020207 (2023)
https://doi.org/10.1063/5.0128197

Work System Redesign in the Finishing Division of the SME Garment Industry Based on Ergonomic Principles

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Abstract. Home Garment Industry is a type of small business that produces clothing on a small scale, both from the point of view of the volume and resources involved. In general, the work done in the garment industry is repetitive and manual, causing musculoskeletal disorders. This disorder causes subjective complaints that are felt to interfere with work activities. Seeing the problems that occurred, further research was carried out to get an ergonomic work system improvement in the finishing division of the garment industry SMEs. The analysis begins by distributing the Nordic Body Map questionnaire to find out subjective complaints. REBA and OCRA analyses were carried out on workers to determine the highest job risk by looking at the final score of the calculations of the two methods. The results of the REBA and OCRA analysis showed that the risk level with the highest score was found in the activity of folding and disposing of threads on clothing. The next stage is the design of alternative designs using the Analytical Hierarchy Process method. The chosen alternative is the second design. Furthermore, after a simulation with software to compare the results of REBA before and after the implementation of the tool, the REBA score was obtained by 4. This means that there is a decrease from a score of 9 (high category) to a score of 4 (medium category).

Keywords: *Nordic Body Map, REBA, OCRA, Ergonomic, Work System Improvement*

INTRODUCTION

Musculoskeletal disorders are one of the diseases related to work. If a physical effort is carried out excessively, both statically and dynamically, and the work is repeated for a long time, it will cause problems known as musculoskeletal disorders.[1]. This musculoskeletal disorder itself is a health problem that often occurs in the world [2]. This musculoskeletal disorder also occurred in one of the home garment industries in Tambora, West Jakarta. Characteristics of work in the garment industry, in general, are material handling (lifting and transport), sitting and standing work positions, high accuracy, high work repetition rate on one or several types of muscles. Although the work done looks light, if it is repeated continuously it can cause physical complaints to workers. In addition to the characteristics of repetitive work, in this garment industry, some workers work on the floor, resulting in an awkward posture. If this posture is carried out continuously, it is possible that physical complaints can become fatal [3]. Seeing the problems that occur, this study was conducted to find out and further analyze the physical complaints experienced by workers in the garment industry, besides that, it is also possible to design tools to improve the work system of the garment industry so that complaints can be resolved.

To overcome physical complaints that occur in a job, an ergonomic analysis of the work is needed both in terms of posture, work environment, and related workstations. Ergonomics is a discipline concerned with understanding the interactions between humans and other system elements, applying theory, principles, data, and methods to design to optimize human well-being and overall system performance. Ergonomics contributes to the design and evaluation of tasks, jobs, products, environments, and work systems so that they can be used according to human needs, abilities, and limitations [4].

With the application of ergonomics principles, it is expected that physical and mental well-being through work-related prevention efforts can increase [5]. In this study, the methods used were Rapid Body Assessment (REBA), The Occupational Repetitive Action (OCRA), and Nordic Body Map (NBM). The first

Proceedings of the 4th Tarumanagara International Conference of the Applications of Technology and Engineering (TICATE) 2021
AIP Conf. Proc. 2680, 020207-1–020207-8; https://doi.org/10.1063/5.0128197
Published by AIP Publishing. 978-0-7354-4698-4/$30.00

thing to do is to map physical complaints on body parts using NBM. NBM is a questionnaire used to determine complaints or musculoskeletal disorders (MSDs) given before and after work [6]. Nordic Body Map is a subjective assessment method, meaning that the success of the application of this method depends on the conditions and situations experienced by workers at the time of the assessment [7]. Rapid Entire Body Assessment (REBA) technique is a body posture analysis system for musculoskeletal risks in performing various jobs. The body posture classification system covered includes the upper arms, forearms, wrists, neck trunk, neck, and legs [2].

Occupational Repetitive Actions (OCRA) is a synthetic index describing risk factors of repetitive actions. Based on the OCRA method, the suggested analysis system is a checklist starting with assigning predetermined values for each of the four main risk factors (recovery period, frequency, force, posture) and additional factors [8]. The OCRA checklist is a tool used to compile an initial risk map due to repetitive work. This map allows for the proportion of jobs or tasks that are classified as varying in color, namely green (no risk), yellow (low risk), red (medium risk), or purple (high risk). By using this tool, risk calculations can be done quickly by analyzing the movements obtained with the OCRA index [9].

To determine the alternative design tools used the AHP method, which is a measurement and comparison made with an absolute rating scale that represents the question, namely how much one element dominates the other related to the attributes or criteria that have been given [10].

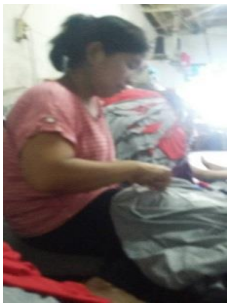
METHODS

Research on SMEs in the Garment Industry began by conducting field studies in the form of interviews, direct observation, and providing a Nordic body map questionnaire. Along with field studies, literature studies are also carried out to explore theories and materials to solve problems that exist in the garment industry. Based on literature study and field study, the problem is formulated. Furthermore, the objectives and limitations of the research were carried out. Complaints and posture data were collected and analyzed using the NBM, REBA, and OCRA methods. The REBA worksheet and the OCRA checklist are used to identify jobs that have the highest risk of physical complaints. After knowing the biggest problems that occur, the design of alternative designs to overcome these problems is carried out. Selection of alternative designs is done using the AHP method.

RESULT AND DISCUSSION

The results of the NBM analysis on finishing workers showed that the highest complaints occurred in four workers. The complaints are on the neck, back, waist, lower waist, and wrists. Based on the analysis using the REBA method, 3 work activities had a high level of risk, namely with a score of 9 for yarn disposal activities, a score of 10 for moving goods, and a score of 8 for the yarn disposal process.

In the calculation of the OCRA Checklist, an activity that has a final score above 22.5 is considered a purple level or categorized as an activity that has a high risk. Based on the analysis using the OCRA Checklist method on this work system, it was found that the highest score obtained was 5 work activities that were included in the purple level or high-risk category. In this OCRA analysis, it can be seen that the yarn disposal activity has a final score of 60.85 for both hands, the clothing preparation activity gets a final score of 28.75 for both hands, ironing activities have a score of 27.51 for the right hand, folding activities clothes with a final score of 42 for both hands, and the last one is clothing tying activities with a final score of 24.94 for both hands. Some of these industrial work activities can be seen in Figure 1.



Yarn Disposal

Clothes Folding

FIGURE 1. Some activities in this work system

The comparison table for the calculation of REBA and OCRA can be seen in Table 1 below.

TABLE 1.Comparison of REBA and OCRA Analysis Results

No	Activity	REBA Score	Risk Level	OCRA Score	Risk Level
1	Yarn Disposal	9	High	60,85	High
2	Clothes Preparation	7	medium	28,75	High
3	Clothes Ironing	7	medium	27,51	High
4	Clothes Moving	10	High	16	medium
5	Giving Handtag on Clothes	4	medium	17,1	medium
6	Clothes Folding	9	High	42	High
7	Clothes Packing	6	medium	10,35	medium
8	Clothes Binding	7	medium	24,94	High

Based on the comparison results that can be seen in Table 1 above, it is concluded that there are 2 that have a score with a high level of risk, namely the yarn disposal activity has a REBA score of 9 and an OCRA score of 60.85 and the folding activity of clothes with a REBA score of 8 and a score of 8OCRA is 42. Activities with the highest level of risk need to improve the work system and implementation to reduce the risk of physical complaints that occur to workers.

Complaints, Expectations, and Needs Analysis.

The analysis of complaints, expectations, and needs was obtained from interviews by finishing workers and SME owners. Interviews were conducted to find out the complaints felt by workers. After knowing the complaints that occurred, interviews were conducted to find out the expectations and needs of the workers in doing their jobs. The results of the analysis of expectations and needs are implemented in the design of work systems to improve these conditions. The following is a table of complaints analysis, expectations and needs can be seen in Table 2 below.

TABLE 2. Complaints, Expectations, and Needs Analysis.

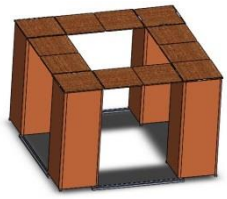
No.	Complaint	Expectation	Need	Design
1.	Workers experience physical complaints in the waist, back, and neck.	Workers no longer experience physical complaints such as pain, aches, and tension in these body parts.	Work is done on a workbench so it is no longer done on the floor.	Tools that are made according to needs, have special functions and have dimensions that are suitable for workers to be comfortable when used.
2.	There is no place to put the clothes to be processed so that the clothes are scattered and mixed	There is a container or place to put the clothes to be processed so they don't fall apart	A place to put clothes to be processed.	A tool that has a storage area for clothes to be processed.
3.	Limited space or unavailability of space for additional work desks.	There is a multifunctional workbench that doesn't take up too much	Multifunctional workbench to do finishing work without too much space.	A multifunctional workbench that is useful for doing work on the finishing section.

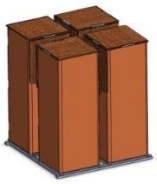
space.

Tool Design

After analyzing complaints, expectations, and needs, the next step that must be done is to incorporate these analyzes into alternative designs that can overcome the complaints that occur. The formulation of alternative designs is done by distributing closed questionnaires to find out the selected characteristics and be considered in a design. Alternative designs are made in the form of a work table that can be used for the process of yarn removing and clothes folding so that workers do not have to do work on the floor. The following is an illustration of the design alternatives made, which can be seen in Table 4 below.

TABLE 3.Alternatives ofTool Design

Alternative	Technical Drawing (3D Drawing)	Descriptions
1		Alternative design 1 is made to do a single job supported by a single clothes holder to keep clothes from falling apart. The cover of the clothes rack is supported by a rail system so that it can be shifted and used as a work table. The material used for alternative 1 is steel. The inside of the clothes tray is supported by a spring system, making it easier for workers to take clothes that are placed in the box.
2		Alternative design 2 can be used for both the folding of the garment and the removal of the yarn. In alternative design 2, if the work to be done is the disposal of threads, then 2 workers can do the work simultaneously by using this workbench. There are 2 places to put clothes before and after the process which is supported by a spring system that makes it easy to pick up clothes. In this alternative, the holder can be inserted under the table, this is to save space when the clothes holder is not in use. In addition, the slidable part of the box is also added with wheels to make it easier when shifting the box.
3		Following the results of the questionnaire, alternative design 3 was made to do more than 2 jobs in one workstation. In this alternative 3 design, 4 places to put clothes are made that allow the process to continue in the finishing division. At first, these workbenches are close to each other. If the worker wants to do his work on a table, each box can be shifted and the material on the sides of the box can be locked to each other so that it becomes a work table to carry out the work process.



Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is used to select existing design alternatives to be realized and implemented. The first stage in making design alternatives is to create a hierarchical structure from AHP for the existing design alternatives. The next stage for AHP is done by giving a perception questionnaire about the importance of the characteristics or criteria that exist in the tool. Questionnaires were distributed to 6 respondents consisting of 4 workers, 1 person is an SME owner and 1 person is a toolmaker (expert). The results of the questionnaire were processed to obtain the geometric mean value followed by normalization calculations to obtain the eigenvector and priority vector values. After the two values are obtained, the consistency test is carried out. If the value of consistency <0.1 then the results of the questionnaire are said to be consistent and can be continued to look for the chosen alternative design.

In the hierarchical structure, it can be seen that there are 6 criteria considered in making alternative designs, namely design, material, functionality, ease of use, comfort in use, and features. After the hierarchical structure is created, it is continued with the calculation of the AHP which has the highest weight. The alternative that has the highest weight is the alternative that is chosen to be realized and implemented. The following is a table for calculating the weights of alternative designs which can be seen in Table 4 below.

TABLE 4.Weight Calculation for Design Alternatives (AHP)

Criteria	Weighted	Weighted alternative			*Composite Weight*		
		Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Design	0,0691	0,26747	0,44069	0,29184	0,01847	0,03044	0,02016
Material	0,1436	0,11709	0,46364	0,41927	0,01682	0,06659	0,06021
Functionality	0,1978	0,42780	0,35367	0,21853	0,08463	0,06996	0,04323
Easy to Use	0,1531	0,41561	0,23313	0,35127	0,06365	0,03570	0,05379
Comfort in use	0,2629	0,18436	0,39896	0,41695	0,04847	0,10481	0,10961
Features	0,1735	0,40597	0,32531	0,26872	0,07042	0,05643	0,04661
Score Total					0,30245	**0,36393**	0,33362

Based on table 5 above, it is known that the weight of alternative 1 is 30.245%, alternative 2 weights 36.393%, and alternative 3 weights 33.362% so that the chosen alternative is alternative design 2.

Dimensions

The dimensions of the aids are determined based on anthropometric data from Indonesians. Body dimensions used are female body dimensions with adjustable principles (5%tile to 95%tile) and extreme individual principles (maximum and minimum). The dimensions used are the elbow height, the distance from the handgrip (grip) to the back in the forward hand position, the span distance from the fingertips of the right hand to the left. After determining the dimensions of the body used, the dimensions for the assistive devices are obtained which can be seen in Table 5 and Figure2.

TABLE 5. Tool Dimensions

Item	**Dimensions**
Table Height	870 mm
Table Width	700 mm
Table Length	1610 mm

Box Height	850 mm
Box width	600 mm
Box Length	700 mm

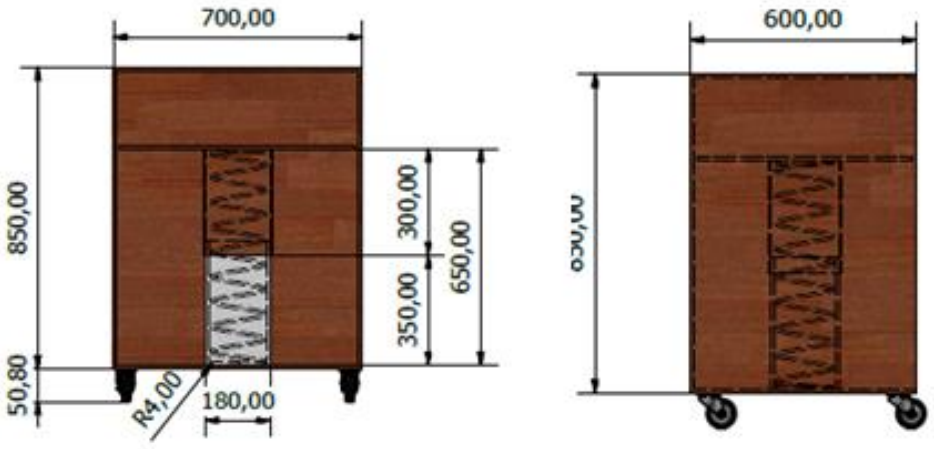


FIGURE 2. Dimensions of Tool Design (mm)

Software Simulation

Software simulation is used to compare the results before the ergonomics intervention with the results of the design of the tool, before making prototypes and field implementation. The software used is CATIA software which can be used to draw 3 dimensions equipped with manikins (human models) with various postures. With this modeling can be seen the operator's posture when using the tool[11][12]. Simulation is done by entering the selected design image and simulating it using CATIA software. The simulation model used is a female mannequin. The simulation is done by moving the mannequin according to the movement of the worker while doing the job. After displaying the mannequin in the software, the next step is to measure the angle of the existing mannequin posture. An image of a mannequin model with an angle can be seen in Figure 3.

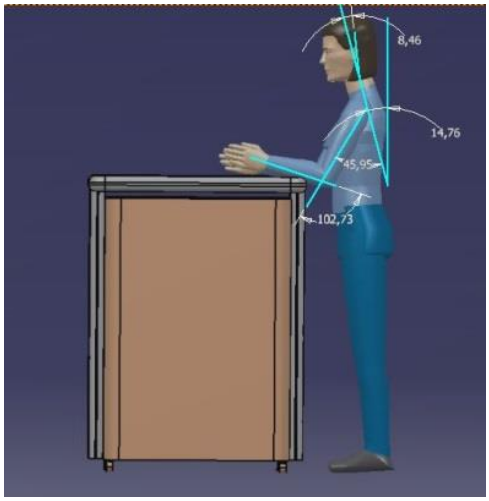


FIGURE 3. Model Mannequin (in Catia)

After determining the angle on the mannequin model, the next step that can be done is to calculate the REBA value based on the angle in the simulation model above. The following is a table of REBA analysis results which can be seen in Table 6.

TABLE 6. REBA Analysis Results

Description	Score
Neck position	+1
Trunk position	+2
Legs	+1
Posture Score in Table A	+2
Force/Load Score	+0
Score A	+2
Upper Arm Position	+3
Lower Arm Position	+2
Wrist Position	+1
Posture in Table B	+4
Coupling Score	+0
Score B	+4
Activity Score	+1
Table C	+3
Final Score	**+4**

Based on Table 6, it is known that the final REBA score obtained for the model simulation is 4. Score 4 states that the risk in the work is medium.

CONCLUSION

Based on the research, analysis, and discussion that has been carried out, it can be concluded that the activities that have the highest occupational risk are yarn disposal and clothing folding with OCRA values of 60.85 and 42, respectively. As for the REBA value for the two activities, a score of 9 is obtained. for thread removal and a score of 8 for the folding process. After knowing the activities that have the highest risk, a tool is designed based on the needs and expectations of the workers. The second alternative was chosen in the selection of alternative design tools using the AHP method. The chosen alternative is the second design. Furthermore, after a simulation with software to compare the results of REBA before and after the implementation of the tool, the REBA score was obtained by 4. This means that there is a decrease from a score of 9 (high category) to a score of 4 (medium category). The limitation of this research is the limited number of respondents. For further research, it is recommended to increase the number of respondents and take a longer research time so that the data collected is more comprehensive

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