JURNAL ILMIAH TEKNIK INDUSTRI
ISSN: 1412-6869 (Print), ISSN: 2460-4038 (Online)
Journal homepage: http://journals.ums.ac.id/index.php/jiti/index
doi: 10.23917/jiti.v23i1.3017

Design of Work Facility Improvements with a Macroergonomic Analysis and Design (MEAD) Approach in SMEs Andri Tofu

Muchlison Anis[1a#], Nurjamal[1b]

Abstract. *Small and Medium Enterprises Andri tofu is an industry engaged in food production which is located in Ngrampal District, Sragen. In the production process there is a non-optimal working system, where the process of setting up the mold tool takes more than 1 minute and the pressing process uses a load of more than 17 kg in the form of using a 20 liter bucket full of water. The purpose of this study is to identify the factors that influence the work system, measure complaints and posture, and design work facility improvement designs. The method used is in the form of Macroergonomic Analysis and Design to design work systems and facilities based on the location of the highest deviation. The results of the study found that there were dominant body complaints on the right hand by 5.18% and mild complaints on the thighs by 1.41%. Improvements to the design of the tool have an adjustable height of 140-170 cm, a width of 72 cm, a height of 57 cm for the feet of the tool, and the pressing uses a gear system with a rack gear of 70 cm and a spin gear of ∅ 6 cm which is driven using a rotary press stirrer.*

Keywords: *MEAD; MSDs; REBA; Work System.*

I. INTRODUCTION

Progress in the industrial sector, especially in the food industry is starting to show its existence to further develop with the application of the latest system, to achieve optimal productivity (Kurniawan et al., 2021; Alami et al., 2023). Progress in the industrial sector has not escaped being accompanied by the development of an organized work system to provide convenience for workers in helping complete their work (Ali et al., 2023). A good work system will have a positive impact on workers who can provide security, safety, and comfort in their work (Putri et al., 2021). The components of an industrial company's work system can be divided into several parts, including work environment problems, company organizational structure, technology, work facilities, work processes, and worker characteristics (Sari et al., 2021). A successful production work system is a system that has been integrated into the entire flow of the production process, starting from the initial stage to the final stage, where the system must be able to integrate humans, machines, and the work environment (De Leite et al., 2020; Ruiz et al., 2023).

Work facilities are physical facilities that can process input or input into the desired form of output (Putri et al., 2020). 3 classes of work facilities can be viewed in terms of their usefulness, namely as work equipment such as printing tools, cutting tools, CNC machines, and so on, then as work equipment such as communication tools, tables, chairs, shelves, and so on, the last as auxiliary equipment such as air conditioners, elevators, attendance machines, and so on (Aksa et al., 2021).

Macro ergonomics is an approach used to analyze and evaluate several factors in the work environment that can affect worker productivity, or can affect the health and comfort of workers. In macro ergonomics, there is a method used in solving a work environment problem, namely the Macroergonomic Analysis and Design (MEAD) method (Hendrick &; Kleiner, 2002).

Some studies that have similar studies in analyzing work system problems with the MEAD method include applying the MEAD method to design ergonomic coil winding machines based on the posture of wire winding workers, which are analyzed by the REBA method (Sukendar et al.,

[1] Industrial Engineering Department, Universitas Muhammadiyah Surakarta, Jl. Ahmad Yani Tromol Pos 01, Pabelan, Kartasura, Sukoharjo, 53162

[a] email: ma228@ums.ac.id
[b] email: nurjamall1407@gmail.com
◆ corresponding author

Submited: 21-10-2023 Revised: 06-06-2024
Accepted: 15-06-2024

2020). The study on the MEAD method in rattan craft SMEs discusses the results of variances used as a basis for designing ergonomic lacquerware spray tools (Tambunan, A et al., 2020). Diansari &; Suhardi (2021) made a permanent shelter design on public transportation using the MEAD method, where the design is produced with human-centered whose improvements refer to the Ministry of Transportation standards. Meanwhile, research conducted by Tambunan, M et al., (2020) MEAD as a tool to identify problems and design workbench repairs that have designs with material specifications using iron, durability of 3 years, blue color, and fixed table leg size.

The novelty in this study will provide variance from the assessment of work posture, MSDs complaints, work environment, and scheduling from workers, which will be used as a basis for designing work facility designs. In addition, this study will provide 2 outputs in the form of tool design design and work rotation implementation.

SMEs Andri tofu is an industry engaged in food production in the form of tofu located in Ngrampal District, Sragen Regency, Central Java. In the production process, several work activities with risky movements or work positions were found when lifting the press load from a bucket filled with full water, which then the load was lifted from the floor to the top of 5 piles of tofu. In addition, the process of setting up the molding tool takes about 1 minute with the position of the worker bent 65-80°. Both processes are inefficient and not ergonomic if done repeatedly. In addition, from the interview results 6 workers stated that the work process with a standing and bending position of approximately 8 hours/day with a mass of more than 5 kg, conventional work facilities, and a less supportive work environment, had an impact on body complaints such as pain in the waist, neck, right shoulder, hands, and feet.

Therefore, a macro ergonomics approach is carried out using the MEAD method to analyze the overall work system in SMEs Andri tofu, both in terms of organization, environment, and developed systems. This research is also supported by an instrument in the form of a Nordic Body Map (NBM) questionnaire which aims to determine and analyze complaints in the area of the worker's body (Dewi, 2020). Due to the work posture that causes discomfort, this study is also supported by the Rapid Entire Body Assessment (REBA) method which aims to assess the posture of workers in doing their work (Pramana &; Cahyani, 2022).

Based on the background, this study aims to identify several factors that affect the work system, measure complaint data and body posture of workers, and design a design to improve work facilities that experience problems, which will be able to create a productive, effective and efficient work system.

II. Research Method

The research was conducted on SMEs Andri tofu with the research subjects, namely 6 workers having an age range of 18-50 years with a gender of 5 men and 1 woman.

This research was conducted with a macro ergonomics approach using the MEAD method which was also supported by the NBM questionnaire and the REBA method. The Macroergonomic Analysis and Design method has 10 steps in the analysis process, as follows (Hendrick & Kleiner, (2002):

Defining organizational subsystems

At this initial stage, a review was carried out on the company regarding (Pradini et al., 2019):

a. Work environment, production input-output, work processes, organizational structure, and consumers.
b. Identify the vision and mission implemented.

Defining production and performance systems

The stage of identifying the production system applied by SMEs Andri tofu in producing tofu from the beginning to the end of production. This stage also determines the level of performance or formation desired by the company.

Defining operating units and work processes

The stage of identifying work units in SMEs Andri tofu. As well as identifying the work process

in each work unit and conducting work analysis to measure the possibility of improvement.

Identifying variants

Is a step to identify weaknesses, deviations or other problems that can reduce performance in the work system. At this stage continued with 2 steps including:

a. NBM questionnaire of body complaints. The NBM questionnaire is intended to determine in detail the parts of the body that experience a form of disorder or complaint in the muscles, joints, tendons, and skeletal bones that cause pain or tingling (Sofyan &; Amir, 2019). In its use, the NBM questionnaire displays body parts that are felt to have complaints with the help of a body map that has 28 parts of complaint areas and is accompanied by complaint levels ranging from Not Sick (TS), Somewhat Sick (AS), Sick (S), and Very Sick (SS) (Mallapiang et al., 2021). The NBM questionnaire requires respondents to provide an assessment of the body part designated number on the body map by providing a checklist (√) based on the type of complaint and the level of complaint experienced (Yulius et al., 2021).
b. Assessment of work posture with the REBA method. In addition, at this stage, analysis is also carried out on work posture with the REBA method at each workstation. The REBA or Rapid Entire Body Assessment method is a method first introduced in applied ergonomics in 2000 by Sue Hignett and Lynn Mc Atamney (Haekal et al., 2020). The REBA method is used to analyze a job based on the position of the human body, which is used to evaluate posture, strength, activity and internal and external factors that can cause repeated injuries to the body (Hignett &; McAtamney, 2000). The application of the REBA method is intended to prevent the risk of injuries related to work posture, especially in skeletal muscles (Wibowo &; Mawadati, 2021).

Create a matrix of variants

This stage is a continuation of the 4th stage, where deviations from the analysis results are made into a variance matrix whose purpose is to identify whether the deviations that occur can affect each other with other deviations.

Analyze personal roles

This step identifies the role of responsible personnel at workstations where there are irregularities. After that, discussions were held to determine several proposed design specifications that are appropriate for supporting the production process.

Function allocation and design integration

This stage makes improvements to the work process and allocates responsible personnel to units that experience irregularities. It became the basis for the selection of the best design specification proposal (Suhartono et al., 2022).

Analysis of perception and responsbility

At this stage will be analyzed the opinions of owners and workers at the station that there are irregularities in SME's Andri tofu.

Redesign work systems and facilities

At this stage, anthropometric measurements of workers' bodies are carried out and anthropometric data processing is carried out, as follows:

a. Data uniformity test. Test to find out whether the data obtained has been uniform or not, where uniform data can be determined if the data is within the upper control limit (BKA) and lower control limit (BKB) (Rosyati et al., 2019).
b. Data adequacy test. Done to find out whether the data obtained is sufficient or not, the data is said to be sufficient if the value of N' < N, otherwise if the data is not enough it can be seen with the value of N' > N (Zetli et al., 2019).
c. Percentiles. In percentiles, states the percentage of individuals in the population who have a body size similar to or smaller than the value of the data (Rosyati et al., 2019).

Implementation, iteration and improvement

Implementation of research results on the production work system.

III. RESULTS AND DISCUSSIONS

Based on the 10 steps of the MEAD method applied to minimize deviations that occur in SMEs Andri tofu, the following results were obtained:

Defining organizational subsystems

SMEs Andri tofu is located in Ngrampal District, Sragen, Central Java which has a production floor area of 109.98 meters^2 and has 6 workers to carry out 15 tofu production processes. The layout of SMEs Andri tofu can be seen in figure 1.

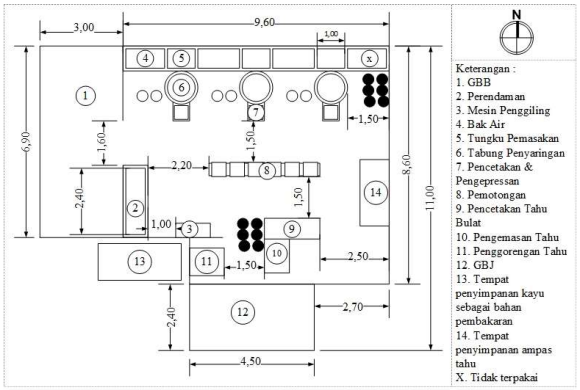

Figure 1. The layout of the facility on the production floor of SMEs Andri tofu

SMEs Andri tofu has his tofu production wastewater disposal located behind the production floor. The distance between the dumping place of the remaining tofu production and the nearest residents' houses to SMEs is around 38 meters. Tofu production wastewater collected in tofu waste places is commonly used by the surrounding community as organic fertilizer. From the journal written by Marian &; Tuhuteru (2019), liquid waste from the rest of tofu production contains nutrients N (Nitrogen) 1.24%, P2O5 (Diphosphorus pentoxide) 5.5%, K2O (Potassium oxide) 1.34%, and C-Organic 5.803%. The floor temperature of SMEs during the production process ranges from 31°-36°C, the cooking and filtering workstation can reach a temperature of 42°C because the workstation is located close to the fireplace.

The organizational structure of SMEs Andri tofu consists of:

1. Leaders, responsible for each production activity, formulate and establish organizational regulations, and determine tofu production planning.
2. Finance, responsible for managing cash flow and handling operational costs and employee payroll.
3. Procurement of materials, responsible for the needs of production materials.
4. Production, responsible for 15 tofu production work processes.

Vision and Mission

The vision of SMEs Andri tofu is to become a growing tofu producer by providing quality products for consumers, as well as becoming a company that can balance the social values of the community.

The missions are:

1. Providing quality raw materials with production processes according to national standards.
2. Provide roles and benefits to the surrounding community.

Defining production and performance systems

SMEs Andri tofu applies a type of production system based on producing output, namely continuous processes, where the process has been arranged and arranged sequentially. The system is based on its operational objectives using a make-to-stock (MTS) system where SMEs Andri tofu has collaborated with tofu traders in the Masaran market, where SMEs try to maintain sufficient tofu inventory to meet consumer demand. While the type of system used in stock management is in the form of first in first out (FIFO), where the materials that come early will be processed first.

The desired level of performance of SMEs Andri tofu, including:

1. Increase work productivity in production to meet consumer needs.
2. Improve operational efficiency by organizing systems more effectively and efficiently to cut production time.

3. Improve physical and mental health, as well as work safety to provide comfort for production workers.
4. Minimize workers' body complaints.

Defining operating units and work processes

In SMEs Andri tofu, there are 15 operating units to produce 3 types of tofu, including white tofu, kempong tofu and, round tofu. In addition, SMEs Andri tofu for their operating units still uses conventional tools in producing the three types of tofu. The use of conventional tools can have a bad impact on workers in producing tofu every day.

With 15 operating units producing tofu every day, it can be based on the work process of producing all three types of tofu. Of the 15 units of tofu production operations, it can be described as follows:

a. Soaking, soaking 180 kg of soybeans with an estimated soaking for 2 hours.
b. Slicing and washing is the stage of slicing and washing soybeans before grinding.
c. Milling, the process of grinding 180 kg of soybeans with a time of about 2-3 hours. Grinding 5 kg of wet soybeans can produce 1 bucket measuring 20 liters.
d. Cooking is the process of cooking tofu dough to boiling.
e. Filtration is the process of separating soybean juice from soybean pulp.
f. Foam removal, removing foam on the surface of soybean juice. The removal of foam is aimed at creating a smoother and denser texture of tofu.
g. Acidification is the addition of vinegar to soybean juice, its function is to precipitate and collect protein, then there is a separation of the top layer with tofu deposits.
h. Printing, molding dough on a tool measuring 50x50x7.5 cm.
i. Pressing is the stage of reducing the moisture content of tofu.
j. Cutting is the process of cutting tofu into sizes of 10x10 cm and 7x7 cm.
k. Soaking, that is, soaking tofu in a bucket that has been cut.
l. Tofu printing is round, the process of printing tofu becomes round.
m. Packaging raw tofu, each package contains 10 pieces of tofu. After packing, the tofu is collected into a bucket of water. For tofu measuring 10x10cm, each bucket contains 20 packs or 200 pieces of tofu, while for tofu measuring 7x7 cm in one bucket, there are 26 packs or 260 pieces of tofu.
n. Frying, frying tofu. For fried tofu kempong as many as 735 pieces and for round tofu as many as 500 grains.
o. Packaging mature tofu, packing fried tofu.
p. Distribution, distributing tofu to the Masaran market of Sragen Regency.

Identifying variants

In the stage of identifying variants, several steps are taken to determine a deviation. In this stage, MSDs complaints were measured with the NBM questionnaire and continued with posture measurements with the REBA method.

a. Nordic Body Map (NBM) Questionnaire. From measuring musculoskeletal disorder complaints using NBM questionnaires to 6 production workers at SMEs Andri tofu, it was found that 2 employees working at cooking stations had scores of 90 and 84 respectively which had a high level of risk, with corrective action "needed immediately". For the 4 workers, those working at milling, frying, cutting, round tofu printing, and tofu distribution stations had scores of 61, 63, 63, and 64 respectively with all four workers having moderate risk levels, with corrective action "may be required not in the future". The results of the NBM questionnaire can be seen in Table 1.

   For the dominant complaints suffered by workers, there was pain in the right hand with a percentage of 5.18% and pain in the shoulder, waist, and calf with a percentage of 4.94%. The lowest complaint of pain in the thigh was 1.41%.
b. Rapid Entire Body Assessment (REBA). Analyzing work posture, measurements are made in several work processes that have a high risk of injury, including cooking,

Table 1. Results of nordic body map questionnaire data to 6 workers

No	Types of Complaints	Worker Score						Total	Percentage
		1	2	3	4	5	6		
0	Pain/stiffness in the upper neck	3	4	3	1	3	3	17	4,00%
1	Stiff pain in the lower neck	3	4	2	1	4	2	16	3,76%
2	Pain in the left shoulder	3	4	3	3	4	4	21	4,94%
3	Pain in the right shoulder	3	4	3	4	4	3	21	4,94%
4	Pain in the left upper arm	2	4	3	3	4	3	19	4,47%
5	Pain in the back	3	4	2	2	3	4	18	4,24%
6	Pain in the right upper arm	2	4	3	4	4	2	19	4,47%
7	Pain in the waist	4	4	3	2	4	4	21	4,94%
8	Pain in the buttocks	2	1	1	1	1	1	7	1,65%
9	Pain in the buttocks	2	1	1	1	1	1	7	1,65%
10	Pain in the left elbow	1	3	1	3	3	2	13	3,06%
11	Pain in the right elbow	1	3	2	2	4	2	14	3,29%
12	Pain in the left forearm	1	4	4	3	3	3	18	4,24%
13	Pain in the right forearm	2	4	4	2	3	4	19	4,47%
14	Left wrist pain	2	4	2	3	4	1	16	3,76%
15	Right wrist pain	1	4	2	2	4	2	15	3,53%
16	Pain in the left hand	3	4	4	3	3	3	20	4,71%
17	Right hand pain	3	4	4	3	4	4	22	5,18%
18	Pain in the left thigh	1	1	1	1	1	1	6	1,41%
19	Pain in the right thigh	1	1	1	1	1	1	6	1,41%
20	Pain in the left knee	4	3	1	1	2	1	12	2,82%
21	Pain in the right knee	4	4	1	1	2	1	13	3,06%
22	Pain in the left calf	3	3	3	4	3	3	19	4,47%
23	Pain in the right calf	3	4	3	4	4	3	21	4,94%
24	Pain in the left ankle	1	3	1	1	2	1	9	2,12%
25	Pain in the right ankle	1	3	1	1	3	1	10	2,35%
26	Pain in the left leg	2	2	2	2	3	2	13	3,06%
27	Pain in the right leg	2	2	2	2	3	2	13	3,06%
Total		63	90	63	61	84	64	425	100,00%

screening, printing, pressing, cutting, round tofu printing, and packaging. Each process will also measure some of the elements that make up the work process, such as moving, lifting, and laying materials. The following is the measurement of the work posture of the tofu production process using the Rapid Entire Body Assessment (REBA) method:

- Measurement of printing work posture. In analyzing the working posture of printing, posture measurements are carried out on the elements of the preparation of the printing tool. More details can be seen in Figure 2.
- Counting group A, the neck has an extension with an angle of 22,06°, score 2. Pungung bends at an angle of 55,45° and rotates 40°, a score of 3+1 with a total score of 4. The legs are not perpendicular with an angular range of >60°, score 2+2, with a total score of 4. The assessment table of known values of group A can be seen in Table 2.

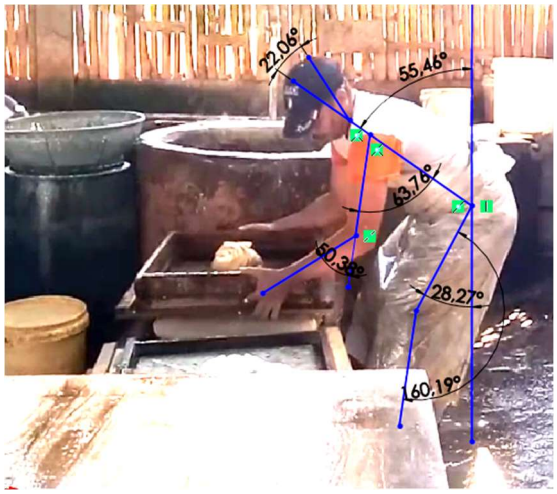

Figure 2. Tofu molding tool setup work posture

Table 2. REBA score group A tofu molding tool setup posture

A		Neck											
		1				2				3			
	Leg	1	2	3	4	1	2	3	4	1	2	3	4
Trunk	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Force/Load			
0	1	2	+1
<5 Kg	5-10 Kg	>10 Kg	Fast load addition

Table 3. REBA score group B tofu molding tool setup posture

B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Coupling			
0	1	2	3
Fit, strong	Acceptable but not ideal	Unacceptable	No handle, forced

Table 4. REBA score group C tofu molding tool setup posture

A	C											
	B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Skor Aktivitas		
+1	+1	+1
The body is in a static state	Repeat a small portion of an activity	There was a rapid change in work attitudes

- In group A, a value of 8 is obtained, then the value is added to the score of the load used by workers. Because the load used by workers is less than 5 kg, the load value is 0, so the final score of group A is 8.
- Group B, upper arm angle of 63,76°, score 3. The forearm forms an angle of 50,38°, score 2. The wrist grasps the printing tool forming an angle of <15° plus the wrist is bent from a straight line, a score of 1+1 for a total score of 2. Assessments in group B, data can be seen in Table 3.
- In group B, a score of 5 is obtained, then the score is added with a grasp score of 1 which is because workers have a grip that is not ideal, then group B gets a score of 6.
- After obtaining the scores of group A and group B, it can be entered into the weighting table of group C, which can later be known as the final value of body posture measurement using the REBA method. More details about group C can be seen in Table 4.
- From the weighting of group C in table 4, a value of 10 is obtained from the results of combining the score of group A which has a value of 8 with the score of group B which has a value of 6. After obtaining a group C score, the score is added to an activity score that has a value of +1 because the printing tool preparation process has a looping movement activity. Therefore, the REBA score is 11, entering a very high level with the type of corrective action "right now" necessary.
- The results of the overall score of the work posture analysis of each workstation can be seen in Table 5.
- Based on work posture measurements, the value of the high-risk level in the screening process with a score of 8, and the very high-risk level in the printing process and pressing process with a range of values of 11 and 12 respectively. So for the printing and pressing process, corrective action is needed at this time also because the body posture measurement score has values of 11 and 12, these values are higher than other work processes. Then variance data can be determined based on printing and pressing which can be seen in Table 6.

Table 5. Final score of the overall working posture of the tofu production process with the REBA method

Station	Element	Score
Cooking	-	3
Filtering	Dough picking	8
	Pouring dough	8
	Preparation of molding tools	4
Foam disposal	-	4
Printing	Preparation of molding tools	11
	Dough transfer	11
Pressing	Press load fastening	11
	Pressing process	12
Cutting	-	5
Round tofu printing	-	7
Packaging	-	7

Create a matrix of variants

The variance matrix, made to find out how much the level of relationship between variances involved in the process in SMEs Andri tofu. In determining the presence or absence of influence on each variant, it is obtained based on consideration of discussions with SME production workers Andri tofu. For the results of the discussion, it can be known the total value of the relationship of each variance which states the level of representation of the deviation that occurs. The greater the value of the relationship of each variance, the greater the deviation that occurs. For more details about the results of the variance matrix, see Table 7.

Based on table 7, it can be stated that the variance with the largest relationship value is in simple work equipment and easily exhausted workers with a total value of 7 each, and some parts of the body feel pain with a total value of 6.

Analyze personal roles

This stage is a continuation of the previous stage, which was created to identify how to control the dominant variant that occurs and the role of personnel responsible for problematic workstations during the tofu production process. At this stage, it is more important to discuss with owners and workers who occur irregularities, so that several alternatives are obtained to minimize

Table 6. Data on the largest deviation variance of the tofu printing and pressing operation unit

Variance Factor	Variance	Cause	Impact
Physical Environment	The presence of stagnant water	There is no water line for water disposal when there is an excess filling of the basin and the waste of water from pressing pools on the production floor	Risk of work accidents such as slipping
	Hot room temperature	There are 4 kilns located in 3 cooking operations and 1 frying pan.	Workers get tired faster
Equipment / Machinery	Work equipment requires large loads	Wooden tools have a heavier mass and are often weathered by vinegar water, and the placement of work facilities is lower than the worker's body	Greater power, and ergonomic work posture resulting in complaints
	The use of overloads	The load used is more than 12 kg	Body complaints MSDs
	The mold filter cloth (batis cloth) is easily torn	There is friction between the fabric and the inside of the mold, and it is often exposed to hot tofu dough	The tofu dough comes out of the mold and the press results in less dense
	Press results are not always the same	Loading using a 20-liter bucket filled with water, for the water content in the bucket is erratic because in the lifting process, the water load is slightly spilled and the use of a torn batis cloth	The press is not solid and tofu is easily destroyed
Working Conditions	Workers are easily exhausted	The work process is carried out repeatedly and the work process is carried out at 3 printing stations	Production workers
		The process is carried out in a standing position for 3 and a half hours without rest periods, at 3 printing stations, the process works with large loads	Decreased productivity, at risk of work accidents
	Some parts of the body hurt	Taking dough from the furnace with a load of more than 5 kg is done in a bent position and then turning sideways	Decreased performance, poor physical and mental health, and absenteeism or absence from work

Table 6. Data on the largest deviation variance of the tofu printing and pressing operation unit (cont'd)

Variance Factor	Variance	Cause	Impact
Working Conditions	Work posture is at risk of injury	The bent body position and twisted waist by lifting weights of more than 12 kg with a right-hand grip are less than ideal	Complaints of MSDs, poor physical health, at risk of work accidents
	The process of setting up the tool takes a long time.	The printing tool consists of 4 components, namely the placemat, the printing box, the calico cloth, and the top cover	Delays in the production process, and ineffective work processes
	The face and arms are often hot	The process of taking tofu dough from the cooking stove is still boiling	Decreased performance and risk of work accidents
Organization	Leaders pay less attention to the workplace	The leader/owner rarely sees directly or supervises the tofu production process	The production process is hampered, and work facilities are not well maintained
	The leadership does not regulate the process of distributing workers' schedules	Workers work in operating units without changing to other operating units, which makes the burden on workers uneven, which does not make workers' work schedules, making workers not change positions or rolling	Workers are saturated with their part of the job, and physical health risks due to the posture of doing the same job for a long time

Table 7. Matrix variance of dominant deviation of tofu printing and pressing operation units

No	Variance	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
1	The presence of stagnant water												X		**1**
2	Hot room temperature								X		X		X		**3**
3	Equipment needs a large load					X	X	X	X	X	X	X			**7**
4	The mold filter cloth (batis cloth) is easily damaged						X								**1**
5	The process of setting up the tool takes a long time			X					X						**2**
6	The use of overloads			X					X	X		X			**4**
7	Press results are not always the same			X											**1**
8	Workers are easily exhausted		X	X		X	X			X		X		X	**7**
9	Some parts of the body hurt			X			X		X		X	X		X	**6**
10	The face and arms are often hot		X						X						**2**
11	Work posture is at risk of injury			X			X		X	X					**4**
12	Leaders pay less attention to the workplace	X	X												**2**
13	The leadership does not arrange the distribution of schedules								X	X		X			**3**

(Fadhillah, 2022)

Table 8. Control of variants and analysis of personnel roles in operating units experiencing dominant deviations

Key Variance	Place	Handling Party	Directly Involved Parties	Variant Control
Workers are easily exhausted	Production Section	Leader	Production Workers	Job rotation, setting fair and appropriate working hours, and improving ergonomic work facilities
Equipment needs a large load	Production Section	Leader	Production Workers	Improvement of work facilities
Some parts of the body hurt	Production Section	Leader	Production Workers	Arrangement of work rotation, ergonomics training and improvement of work facilities

deviations that occur. More details can be seen in Table 8.

Based on the three key variants determined, it can be controlled by rotating work so that workers are not focused on one job continuously, setting fair working hours for all workers and following the work process carried out, and improving work facilities that have the greatest level of risk of complaints by thoroughly evaluating the work process that is still being carried out with a large load and later identified several tasks that can be minimized to improve efficiency, productivity and work safety. In addition, ergonomics training is carried out in every work process.

Function allocation and design integration

Based on the results of posture measurements, the largest deviations occurred at printing and pressing stations with REBA scores of 11 and 12 respectively which were included in the very high category. The old design of printing and pressing tools in SMEs Andri tofu takes a lot of production time, uses heavier loads, and the process of using tools that make postural errors arise in workers. This is because the work facilities are not ergonomic, so an improvement is needed to minimize the problems that occur. The old design of the printing and pressing work facility has the dimensions of a printing tool with an outer width length of 52x52 cm, a height, of 7 cm, an inner width length of 50x50 cm, and a base tray with a size of 59x59 cm. For more details about the initial work, facilities can be seen in Figure 3.

Based on figure 3, improvements can be made by changing work facilities that still require a long setup process and using excess load, to be more effective and efficient which can later increase worker productivity. From discussions and interviews, owners and workers are faced with choosing the specification of the repair design of the tool. The results of the discussion in determining the design specifications can be seen in Table 9.

Figure 3. Fasilitas kerja pencetakan dan pengepressan tahu sebelum perbaikan desain

Table 9. Design specifications selected design improvement of tofu printing & pressing work facilities

Design	Specification
Material	Stainless Steel
Tall	Adjustable
Wide	Customized Mould
Thickness	0,2-0,4 cm
Loading	Gear System

Analysis of perception and responsbility

From the results of the selected design design specifications, it can be determined that the design specifications for improving printing and pressing work facilities by replacing molded materials originally made of wood, which after 2 years of use the wood began to experience loss due to frequent exposure to water and vinegar acid. Therefore, the repair material uses stainless steel, because it has the strength to withstand loads and is not corrosion, which can extend the service life of the tool. The height of the tool is adjustable so that it can be adjusted to the height of the worker, which uses the 5th percentile and 95th dimension of standing eye height for 6 SME workers. The width of the tool is adjusted to the size of the printed tofu, which is the size of the tofu by 50x50x4 cm. For the thickness of the selected material of 0.2-0.4 cm, the foot frame uses a stainless steel pipe thickness of 0.3 cm and the table frame uses hollow stainless steel thickness of 0.2 and 0.3 cm because the table mat will receive a load from the tofu pile. The use of wheels facilitates transfer from tools and molds that are installed directly on the tool to reduce set-up time. As for loading or pressing that previously used a 20-liter bucket filled with water lifted from the floor to the top of the mold, the process resulted in an error in non-ergonomic work posture. Therefore, the loading is determined using the steering press lever with a motion system using rack gear and spin gear driven using a steering wheel, the aim is to ease the burden on workers in the pressing process.

Redesign work systems and facilities

In the process of redesigning work facilities that are ergonomic and in accordance with the worker's body, anthropometric measurements of the worker's body are carried out. The body dimensions measured by the six workers were the dimensions of standing eye height (TMB), fingertip height (TUJ), forward hand reach (JTD), and hand width (LBT).

Table 10. Uniformity test of anthropometric data of 6 workers on 4 body dimensions

	Data				
	TMB	TUJ	LBH	JTD	LBT
	139	50,5	42,5	68,6	8,8
	156	58	50,4	77,4	9,9
	157	58,5	47	79	9,5
	164	60	50	82,5	10,4
	163	59,7	47	80	9,9
	151	57,4	45,9	75,4	9,5
X	104	57,35	47,13	77,15	9,67
SD	6,6	3,5	2,9	4,82	0,54
BKA	117,2	64,35	52,92	86,8	10,7
BKB	90,8	50,35	41,34	67,5	8,59

Table 11. Test the adequacy of anthropometric data of 6 workers on 4 body dimensions

	Data				
	TMB	TUJ	LBH	JTD	LBT
	139	50,5	42,5	68,6	8,8
	156	58	50,4	77,4	9,9
	157	58,5	47	79	9,5
	164	60	50	82,5	10,4
	163	59,7	47	80	9,9
	151	57,4	45,9	75,4	9,5
Σx	930	344,1	282,8	462,9	58
Σx^2	144572	19795,35	13371,22	35829,13	562,12
(Σx^2)	864900	118404,81	79975,84	214276,4	3364
N	6	6	6	6	6
N′	4,684	4,963	5,031	5,215	4,147

Table 12. Percentile data of 6 workers on 4 anthropometric dimensions

No	Dimention	5	50	95
1	TMB	139,89	-	170,11
2	TUJ	-	57,35	-
3	JTD	-	77,15	-
4	LBT	-	8,67	-

- Data uniformity test. From Table 10, it can be stated that the uniformity test result data is declared uniform, this is because anthropometric data to 6 workers are between the upper control limit and the lower control limit.
- Data adequacy test. From Table 11, it is obtained that the value of N' is smaller than the value of N or N' is smaller than the amount of data, then the anthropometric data of the 6 workers is declared sufficient.
- Percentil. Because the height of the tool to be redesigned has an adjustable height or the height of the tool can be adjusted and changed, then for the dimensions of the standing eye height using the 5th percentile and 95th percentile, which will be the minimum tool height using the 5th percentile and the maximum tool height with the 95th percentile. For anthropometric dimensions of other body parts in the dimensions of fingertip height, dimensions of hand reach forward, and dimensions of hand width using average dimensions or using the 50th percentile from body anthropometric data to six SME workers Andri tofu. For percentile data can be seen in Table 12.

In improving the design of printing and pressing work facilities using anthropometric data of all workers, so that the percentile value needed in the redesign is obtained. For the results of improving the design design of printing and pressing work facilities, tofu can be seen in Figure 4

Based on figure 6, the height of the tool is adjustable with a minimum height using the 5th percentile, a standing eye height is 140 cm, and a maximum height using the 95th percentile of 170 cm. For a tool width of 72 cm based on the size of a tofu tray of 59 cm, a foot frame with a diameter of 4 cm with a tofu tray allowance and a tool of 7 cm on each side. The material uses stainless steel pipe diameter of 4 cm thickness of 0,3 cm and stainless steel hollow 4x4 cm thickness of 0,3 cm. The height of the tool foot uses a 50th percentile of the height of the fingertip which has a size of 57 cm, and the foot is equipped with wheels, which the tool can be moved easily. The repair design uses a rack gear and spin gear system with a drive in the form of a steering wheel which is used as a tofu pressing process and is placed on the right side of the tool. For the placement of the steering press based on the 50th percentile dimension of the hand reach forward with a distance of 77.15 cm. The lever handle is coated with a material made of rubber which can avoid slippery levers when pulled and can function as an insulator. Lever handle size based on 50th percentile Hand width dimensions of 8.7 cm.

In addition to improving tool design, work system improvements were also made that can be applied directly to SMEs. Improvement of the

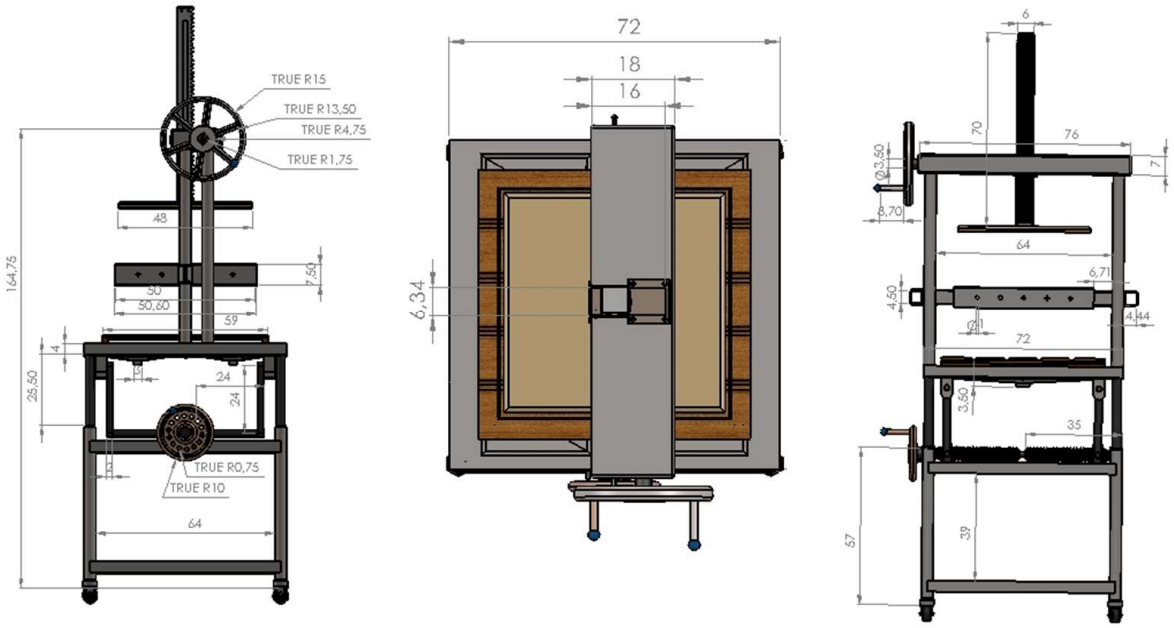

Figure 4. Design design, improvement of work facilities, printing & pressing tofu, adjustable

work system based on the same work process and carried out in the long term, which does not rule out the possibility of workers experiencing several complaints in their work, including boredom, stress, pain in body parts, and can reduce concentration on work. Improvements that can be applied directly in the form of job rotation. In improving this work scheduling system, SMEs Andri tofu has 6 workers, consisting of 5 men and 1 woman. Job rotation is carried out for 2 weeks in 1 month with three job division rotation schedules.

Implementation, iteration and improvement

The last stage in the form of implementation, iteration and improvement processes can be done by simulating whether the results obtained can be applied to the organization or not to minimize deviations that occur on the production floor. In addition, the application of research results can be directly applied to the place where deviations occur.

Simulation of tool repair design design

The test of the results of the tool repair design was carried out using the Rapid Entire Body Assessment (REBA) method with simulation using CATIA software. The simulation was carried out using the 50th percentile or the average percentile with a height of 165,67 cm, for the simulation test as follows:

Counting group A, the neck flexion with an angle of 24,23°, score 2. Perpendicular bend with an angle of 0°, score 1. Perpendicular legs with a score of 1. From the assessment, it can be known the value of group A in Table 13.

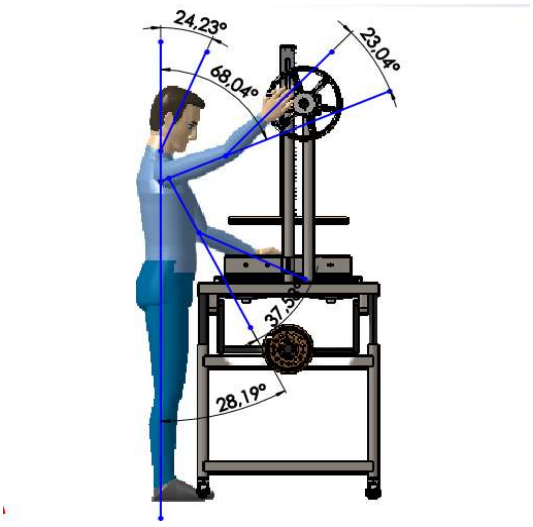

Figure 5. Measurement of working posture after design improvement of printing & pressing tools

Table 13. REBA score group A work posture repair design printing & pressing tools

A		Neck											
		1				2				3			
	Leg	1	2	3	4	1	2	3	4	1	2	3	4
Trunk	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Force/Load			
0	1	2	+1
<5 Kg	5-10 Kg	>10 Kg	Fast load addition

Table 14. REBA score group B work posture design repair printing & pressing tools

B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Coupling			
0	1	2	3
Fit, strong	Acceptable but not ideal	Not acceptable	No grip, forced

Table 15. REBA score group C work posture repair design printing & pressing tools

A	C											
	B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Skor Aktivitas		
+1	+1	+1
The body is in a static state	Repeating a small part of the activity	Quickly there was a big change in work attitudes

Group A obtained a value of 1 and then added the load used by workers. Because the load is less than 5 kg, the load value is 0, so the final score of group A is 1.

Group B, upper arm angle of 68.04 · , score 3. The forearm forms an angle of 23.04 · , score 2. The wrist grasps the steering press to form an angle of <15 · with a score of 1. Assessments in group B table which can be seen in Table 14.

In group B a score of 4 is obtained, then the sum of the grip scores of 0 is because workers have a right and strong grip, then group B gets a score of 4.

After obtaining the scores of group A and group B, it can be entered into the weighting table of group C, which can later be known as the final value of body posture measurement using the REBA method. More details can be seen in Table 15.

From the weighting of group C in Table 15, a value of 2 is obtained from the results of combining the score of group A which has a value of 1 with the score of group B which has a value of 4. After obtaining the score of group C, the score is added to an activity score that has a value of +1 because the process of preparing the printing tool has a looping movement activity. Therefore, the REBA score is obtained at a value of 3, entering the low level.

From the simulation test of the tool with the REBA method, it can be stated that there is a reduced risk of work posture errors which previously reached values of 11 and 12 with a very high category, which after redesign had an

Figure 6. Comparison of design plans of printing & pressing work facilities before and after repair

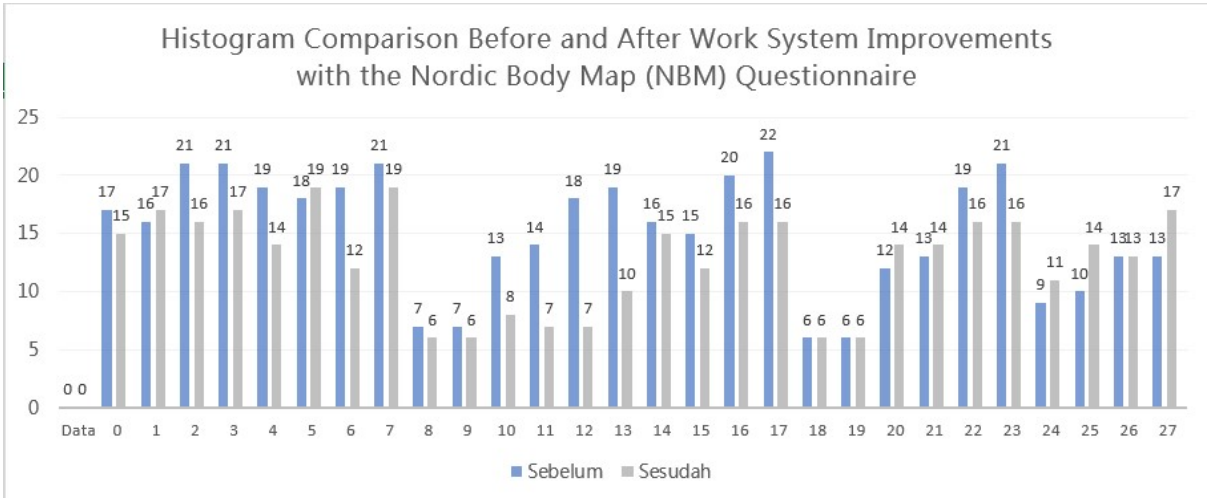

Figure 7. Comparison of nordic body map questionnaire results regarding musculoskeletal disorder complaints before and after improvement

REBA score of 3 with a low category. Therefore, the design of printing & pressing work equipment improvements can be used as a solution to minimize problems that occur in SMEs Andri tofu, such as reducing body complaints due to the use of excessive loads and errors from work posture. For this reason, we can see a comparison of the design of work tools before and after repair in Figure 6.

Improvement of the work system can be done by doing a work rotation every 2 weeks for 1 month. From the results of the implementation, testing can be carried out by distributing the Nordic Body Map questionnaire back to 6 workers. The questionnaire results showed a decrease in overall MSDs complaints of workers, all of which were in the medium range or below the value of 70. A comparison chart of body complaints before and after repair can be seen in Figure 7.

Based on measurements with the NBM questionnaire, there was a decrease in the level of complaints felt by workers after the job rotation process twice a month, where all workers were in the moderate complaint level in the range of 50-70. Complaints felt by workers after rotation was pain in the waist with a percentage of 5,29%, and pain in the lower neck, right shoulder, and right leg with a percentage of 4,74% each. This shows that there is an influence of the implementation process of improving work scheduling in SMEs Andri tofu.

IV. Conclusion

Factors that affect the work system of SMEs Andri tofu include, puddles on the production floor due to the absence of water flow lines, workers easily exhausted due to the work process carried out in a standing position for 8 hours with a looping process and the use of excess loads, complaints of several parts of the worker's body due to excessive loads and wrong work postures, the use of work tools that require a load of more than 12 kg, and workers work on the same workstation continuously.

The results of the NBM questionnaire found 2 workers who had high complaint rates reaching 90 and 84, with dominant complaints suffered by all workers, pain in the right hand with a percentage of 5.18%, pain in the shoulder, waist, and calf with a percentage of 4.94%, and pain in the left hand with a percentage of 4.71%. Measurement of work posture using the REBA method states that the screening process has a score of 8 with a high level, and a very high-risk level in the printing process and pressing process with values of 11 and 12 respectively. So for the printing and pressing process, corrective action is

needed right now, because the value is higher than other work processes.

The design of the improvement of tofu printing and pressing work facilities is made with adjustable height using a 5th percentile value of 140 cm for minimum height and 95th percentile of 170 cm for maximum height. The width of the tool is 72x72 cm which is based on the length of the tofu tray width of 59x59 cm with allowance between the tray and the length of the inner width of the tool of 7 cm. The mold has an outer size of 50.3x50.3x7.5 cm which can be adjusted printing position. The height of the tool is adjustable using the working principle of a horizontal thread with a drive in the form of a steering circle on the side of the tool. The pressing working system uses the working principle of 70 cm rack gear and 6 cm spin gear. The results of testing the improvement of tool design with the REBA method simulated with CATIA software found a decrease in the REBA score to 3 with a low level, which was previously 11 and 12 with a very high level. Implementation can be made direct improvements to the work system of SMEs Andri tofu with work rotation every 2 weeks with 3 distribution schedules, which is obtained from the implementation for 1 month which states a reduction in body complaints in workers with a moderate level.

REFERENCES

Aksa, Y. D. T., Utari, W., & Indrawati, M. (2021). Analisis Pengaruh Lingkungan Kerja, Komunikasi Dan Fasilitas Kerja Terhadap Semangat Kerja Pegawai Kantor Pertanahan Kabupaten Ponorogo. *JAMAS*. 2(2), 84-92.

Alami, A. H., Olabi, A. G., Khuri, S., Aljaghoub, H., Alasad, S., Ramadan, M., & Abdelkareem, M. A. (2023). *3D Printing in The Food Industry: Recent Progress and Role in Achieving Sustainable Development Goals. ASEJ*. 1-14.

Ali, M., Salah, B., & Habib, Tufail. (2023). *Utilizing Industry 4.0-Related Technologies and Modern Techniques for Manufacturing Customized Products – Smart Yogurt Filling System. Journal of Engineering Research*. 1-8.

De Leite, L. O. M., Sasaki, A. M., Bitencourt, R. S., Okumura, M. L. M., & Canciglieri, O. (2020). *Humanization and Macroergonomics: An Analysis In The Billing Sector Of A University Hospital In Paraná. IOS Press*. 12, 201–210.

Dewi, N. F. (2020). Identifikasi Risiko Ergonomi Dengan Metode Nordic Body Map Terhadap Perawat Poli RS X. *JSHT*. 2(2), 125-134.

Diansari, B. N., Suhardi, B., & Susanto, N. (2021). *Macroergonomic and Analysis Design* (MEAD) *for Permanent Shelter of Public Transportation. Proceedings of The Second Asia Pacific International Conference on Industrial Engineering and Operations Management.*

Fadhillah, A. (2022). Analisis Perancangan Fasilitas Stasiun Kerja Pada Bagian Produksi dengan Menggunakan Metode Macroergonomic Analysis and Design (MEAD) dan *Software Master Cam* di PT. Kreasi Semesta Raya (Otogard). *SJIE*. 3(1). 28-30.

Haekal, J., Hanum, B., & Prasetio, D. E. (2020). *Analysis of Operator Body Posture Packaging Using Rapid Entire Body Assessment* (REBA) *Method: A Case Study of Pharmaceutical Companyin Bogor, Indonesia*. *IJERAT*. 06(07), 27–36.

Hendrick, H. W., & Kleiner, B. M. (2002). *Macroergonomics: Theory, Methods, and Applications*. London: Lawrence Erlbaum Associates.Tarwaka., Bakri, S. H. A., & Sudiajeng, L. (2004). *Ergonomi untuk Keselamatan, Kesehatan Kerja dan Produktivitas*. Surakarta: UNIBA Press.

Hignett, S., & McAtamney, L. (2000). *Rapid Entire Body Assessment* (REBA). *Applied Ergonomics*. 31(2), 201–205.

Kurniawan, A. S., Rahayuningsih, S., & Safi'i, I. (2021). Pendekatan Ergonomi Makro Pada Pengaruh Lingkungan Kerja Terhadap Kinerja Karyawan (Studi Kasus UD. Ulin Putra). *JURMATIS*. 3(1), 63–77.

Mallapiang, F., Azriful, Nildawati, Syarfaini, Muis, M., & Adriansyah. (2021). *The Relationship of Posture Working with Musculoskeletal Disorders* (MSDs) *in the Weaver West* Sulawesi Indonesia. *Gaceta Sanitaria*. 35(1), 15–18.

Marian, E., & Tuhuteru, S. (2019). Pemanfaatan Limbah Cair Tahu Sebagai Pupuk Organik Cair pada Pertumbuhan dan Hasil Tanaman Sawi Putih (*Brasica pekinensis*). *Agritrop*. 17(2), 134-144.

Pradini, A. H., Lucitasari. D. R., & Putro. G. M. (2019). Perbaikan Sistem Kerja Dengan Pendekatan *Macroergonomic Analysis and Design* (MEAD) Untuk Meningkatkan Produktifitas Pekerja. *OPSI*. 12(1), 36-47.

Pramana, A. N., & Cahyani, M. T. (2022). Analisis Postur Kerja Dengan Metode Rapid Entire Body Assessment (REBA) dan Keluhan Subjektif Muskuloskeletal pada Petani Bawang Merah di Probolinggo. *IJHECO*. I3(1), 30-38.

Putri, D. S. B. (2021). Analisis Sistem Kerja untuk Meningkatkan Produktivitas Pegawai Negeri Sipil dengan Pendekatan Macroergonomic Analysis and Design. *Serambi Engineering*. 6(4), 2449-2458.

Putri, R., Zulfadil, & Maulida, Y. (2020). Pengaruh Disiplin Kerja dan Fasilitas Kerja terhadap Kepuasan Kerja dan Produktivitas Kerja Karyawan PT Subentra Kota Pekanbaru. *KIAT*. 31(2), 56-68.

Rosyati, D., & Ahyadi, H. (2019). Disain Ergonomis Tempat Operasi Khitan Untuk Mengurangi Keluhan Muskuloskeletal Dengan Metode Rapid Entire Body Assessment (REBA) Dan Pengukuran Anthropometri. *Bina Teknika*. 15(1), 69-76.

Ruiz, E., Torres, M. I., & del Pozo, A. (2023). *Question Answering Models for Human-Machine Interaction in The Manufacturing in Industry. Computers In Industry*. 151, 1-12.

Sari, W. A. M., Suhardi, B., & Suletra, I. W. (2021). Pengaruh Kondisi Sistem Kerja Terhadap Stress Kerja dengan Menggunakan *Macroergonomic Organizational Questionnare Survey* (MOQS). *INTECH*. 7(1), 30–38.

Sofyan, D. K., & Amir. (2019). *Determination of Musculoskeletal Disorders* (MSDs) *Complaints Level with Nordic Body Map* (NBM). *IOP Conference Series: Materials Science and Engineering*. 505(1).

Suhartono, R., Suhendar, E., & Wibisono, D. (2022). Analisis Dan Desain Meja Kerja Menggunakan *Macroergonomic Analysis and Design* Pada PT. Control Systems Para Nusa. *JTM*. 20(2), 81–88.

Sukendar, I., Arifin, B., & Addin, F. S. (2020). *Analysis and Design of Coil Rolling Machines on Robot Solenoids using Macroergonomic Analysis Method and Design* (MEAD) *and Rapid Entire Body Assesment* (REBA) *Based on Arduino Microcontroller*. *IJESTE*. 3(2), 35–47.

Tambunan, A., Sitanggang, E. R., & Mardhatillah, A. (2020). *Design of Vernis Sprayer Using Macroergonomic Analysis and Design*. *IJSTM*. 1(3). 251-255.

Tambunan, M. M., Napitupulu, H. L., Rizkya, I., & Syahputri, K. (2020). *Design of Work Facilities Using Quality Function Deployment* (QFD*) and Macro Ergonomic Analysis Design* (MEAD). *IOP Conference Series: Materials Science and Engineering*. 801(1).

Wibowo, A. H., & Mawadati, A. (2021). *The Analysis Of Employees' Work Posture By Using Rapid Entire Body Assessment* (REBA*) and Rapid Upper Limb Assessment* (RULA). *IOP Conference Series: Earth and Environmental Science*. 704(1).

Yulius, H., Barlian, E., Fatimah, S., Heldi., & Umar, I. (2021). *Improvement of Work System and Physical Work Environment to Increase Worker Productivity in Natural Tofu Factory. CAJLPC.* 02(07), 31-38.

Zetli, S., Fajrah, N., & Paramita, M. (2019). Perbandingan Data Antropometri Berdasarkan Suku Di Indonesia. *JRSI.* 5(1), 23-34.