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Design of an ergonomic tofu cutting tool in the tofu industry of Aceh

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Abstract: Tofu MSMEs are among those who managed to survive the pandemic, and their numbers continue to grow to this day. However, the number of these MSMEs pales in comparison to the production technology they utilize. The production process in tofu MSMEs still uses traditional methods. One of these methods is used at the cutting workstation. Typically, the tofu cutting workstation lacks specialized tools for tofu cutting, forcing workers to rely on knives and rulers, resulting in repetitive movements during the cutting process. This prolongs the tofu cutting process and results in uneven tofu cuts. Additionally, the manual cutting process and the unsuitability of the cutting area for the workers' bodies lead to them bending over while cutting. Therefore, many workers complain of pain in their body parts. This research uses the Nordic Body Map questionnaire to identify the body parts of workers experiencing pain and the Rapid Upper Limb Assessment method to assess workers' posture. This research also uses Catia V5 software for simulating the proposed work posture. The results of the Nordic Body Map assessment show that out of the 21 MSMEs analysed, 4 MSMEs a high level of risk and 17 others have a moderate level. According to the posture assessment results of the six evaluated workers, one tofu SME has a very high-risk level with a score of 7, one tofu SME has a very high-risk level with a score of 6, and four others have a high-risk level with scores of 5. We utilized Catia V5 software to simulate the proposed design of the tofu cutting tool, adjusted to the worker's body size, and received a score of 3, indicating a medium risk level of musculoskeletal disorders. We expect this tool to reduce risk levels, decrease cutting duration, minimize repetitive motions, and produce more consistent cuts.

Keywords: *Anthropometry, Musculoskeletal disorders, Micro small and medium enterprises, Nordic body map, Rapid upper limb assessment.*

1. Introduction

Tofu is a highly popular food among Indonesians due to its affordable price and high protein content, making it a common selection for household consumption. Households not only consume tofu but also utilize it as an ingredient in various other dishes. Small businesses in Indonesia sell tofu commonly prepared as stuffed tofu, in the form of fried appetizers. Soybeans, the third most important food crop after rice and corn, are the source of tofu, a food product [1]. Tofu is produced using the main raw material, which is soybeans, and during the process, vinegar or nigari (seaweed extract) is also added to make the soy milk coagulate. Aceh generally produces two types of tofu: Tofu Sumedang and Tofu Sayur. These two varieties of tofu possess distinct shelf life and are produced using slightly different ways. The production process of Sumedang tofu starts with the soaking of soybeans, followed by grinding, boiling, filtering, coagulating the soy milk, molding, and cutting the tofu. Meanwhile, vegetable tofu starts with the soaking of soybeans, followed by grinding, filtering, boiling, coagulating the soy milk, molding, and cutting the tofu. Small and medium enterprises in Indonesia typically produce tofu, resulting in the widespread distribution of tofu factories across all regions. Micro and

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medium enterprises still classify tofu factories as one of the few surviving manufacturing industries [2]. Because small-scale manufacturing has limited resources, SMEs in Indonesia often face ergonomic issues. The production process of MSME tofu generally still uses traditional methods. In some MSMEs, there is a lack of designated areas for tofu cutting, necessitating the use of knives and rulers as cutting implements, resulting in numerous repeated motions during the cutting procedure. The tofu cutting procedure becomes protracted and inefficient. This thus leads to irregular slices of tofu. Additionally, the manual cutting process, and the cutting area are unsuitable for the workers' bodies, resulting in them bending over during the tofu cutting procedure. Because of this, many workers complain of back pain. Based on the issues, the aim of this research is designing an ergonomic tofu cutting tool, which can reduce the duration of tofu cutting, produce more regular tofu slices, and reduce the risk of musculoskeletal disorders, thereby protecting workers from potential work-related diseases.

2. Related Literature

2.1. Ergonomic

Ergonomics derives from the Greek word's ergon, meaning work, and nomos, meaning rule or law. Ergonomics comprises a set of principles guiding worker methods and attitudes. Ergonomics is a systematic scientific discipline that focuses on human characteristics, capabilities, and constraints to develop the optimal work systems that improve reaching the goal of objectives through effectiveness, efficiency, safety, and comfort [3][4][5].

2.2. Nordic Body Map

The goal of the Nordic Body Map is to better understand which body parts cause pain or discomfort during work. They can identify and assess their pain complaints with the NBM, thanks to its structured and standardized questionnaire. The Nordic Body Map questionnaire is the most frequently used to determine employee discomfort. The Nordic Body Map (NBM) is the most used questionnaire to identify discomfort or pain in the body. The questionnaire asks respondents to indicate the presence or absence of disturbances in specific areas of the body [6][7][8].

2.3. Musculoskeletal Disorders

MSDs is one of the occupational diseases. Individuals experience chronic disorders in muscles, tendons, and nerves due to uncomfortable postures, work duration, frequency, and repetitive movements [9][10]. Muscle damage can include muscle strains, inflammation, and muscle degeneration, while bone damage can include bruises, micro fractures, fractures, or twists [11][12][13]

2.4. Rapid Upper Limb Assessment

Dr. Lynn McAtamney and Dr. Nigel Corlett from the University of Nottingham, England, developed the RULA method in 1993. RULA is a highly effective method for assessing the risk level of activities dominated by upper body movements, such as hands, arms, shoulders, neck, and back. The RULA method offers a thorough and detailed evaluation of every body part, including group A (upper arm, lower arm, wrist, wrist twist) and group B (neck, trunk, and legs), as well as muscle use (static or repetitive), and posture [14][15][16][17][18]. Dempsey's survey results indicate that international ergonomics experts most widely use the RULA method due to its easy-to-understand and user-friendly procedure. RULA worksheet can be seen in Figure 1.

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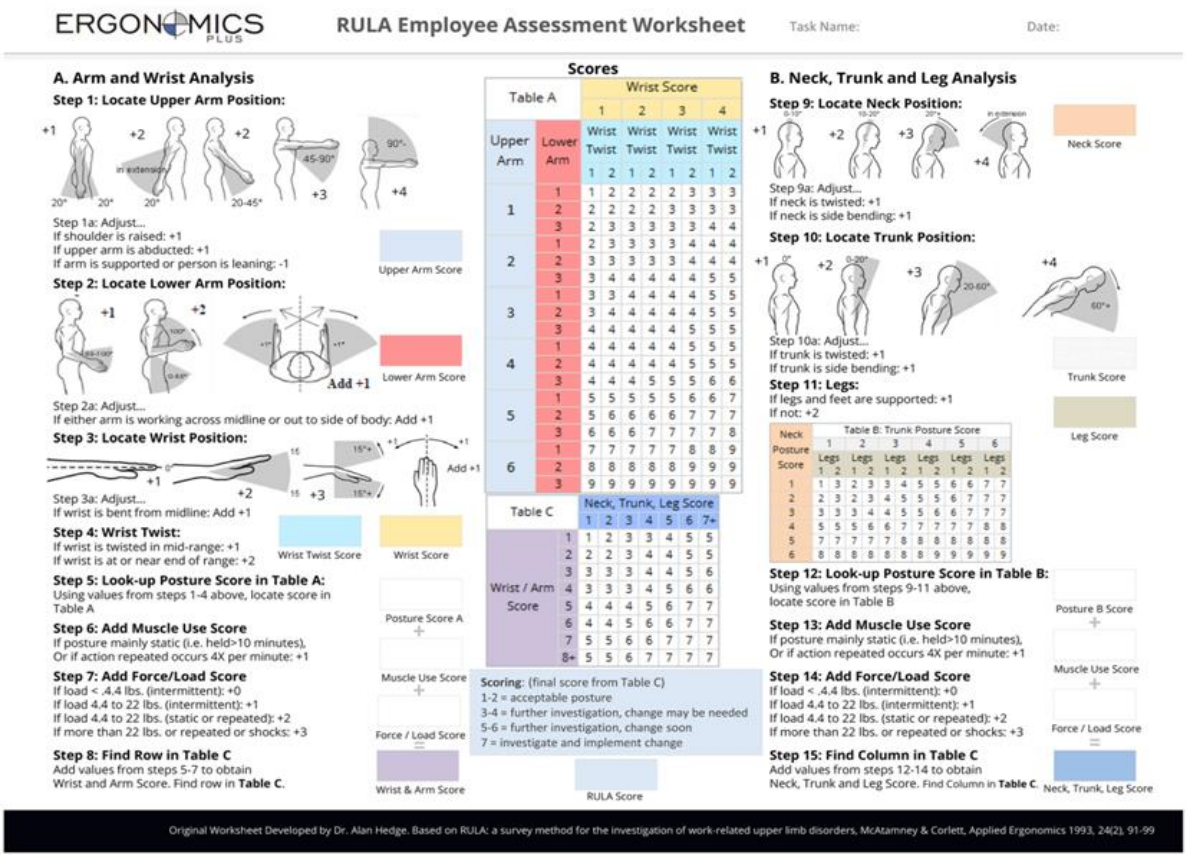

Figure 1.
RULA worksheet.

2.5. Anthropometry

Anthropometry refers to the act of measuring the human body. By obtaining accurate measurements of the workers' physiques, it becomes possible to design work equipment, workstations, and items tailored to the workers' body dimensions. This ensures optimal work comfort, health, and safety. Consideration of human body proportions has been present for a significant amount of time, including several centuries in the past. Indonesians have incorporated anthropometric considerations into the construction of work equipment, housing, and other facilities, ensuring their alignment with human body sizes [19][20][21][22].

3. Research Methodology

This research conducted by communicate with field research at 21 tofu SMEs in Lhokseumawe and North Aceh. Data collection was conducted by documentation, interviews, and the filling out of the Nordic Body Map questionnaire during the tofu cutting process at the Tofu SMEs. The data processing involved the analysis of several methodologies employed in this research. The phases are as follows:

1. Analysis of the Nordic Body Map questionnaire results to ascertain potential complaints associated with muscle areas in workers.
2. Assessment of the Rapid Upper Limb Assessment (RULA) through work process documentation utilizing Ergo Fellow to determine the risk level for workers.
3. Analysis of anthropometric data to derive optimal measures for implementation in product design, succeeded by design execution with Fusion 360 software.
1. Simulation to assess work posture with the Rapid Upper Limb Assessment (RULA) methodology within Catia V5 software.

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4. Result of the Study

The tofu production method involves six stages: soaking, milling, filtering, boiling, pressing, and cutting. The tofu production process predominantly uses basic tools that focus physical strength and ergonomic posture. The tofu producing procedure is similarly relevant in Lhokseumawe and North Aceh. Basic work aids include the soybean grinder, the press, and the cutter. This study focuses on cutting workstations. Observations of several MSMEs indicate the lack of an established space for tofu cutting; instead, they utilize knives and rulers as cutting tools, along with a high frequency of repeated motions during the operation. Consequently, the tofu cutting procedure is time-consuming and inefficient. This also results in irregular tofu cutting. Moreover, the manual cutting procedure, and the cutting area are incompatible with the workers' posture, resulting in their need to bend over when cutting. Non-ergonomic or unnatural work postures that may, over time, increase the risk of Musculoskeletal Disorders (MSDs). MSDs are conditions affecting nerve or muscle tissue, resulting from the cumulative and repetitive nature of continuous motions during labor. This study will assess the work posture of employees. Table 1 give the information regarding tofu SMEs in Lhokseumawe and North Aceh.

Table 1.
MSMEs Tofu in aceh.

No	MSMEs	Worker	No	MSMEs	Worker	No	MSMEs	Worker
1	TM	3	8	ZZM	5	15	TAS	4
2	JP	3	9	SWU	4	16	ATU	3
3	MZ	4	10	PAH	4	17	TDH	5
4	IH	3	11	UTZ	3	18	THP	3
5	MT	2	12	JTU	5	19	DOI	2
6	MG	4	13	JLT	5	20	TSH	3
7	MM	4	14	MIJ	4	21	TBD	4
Total worker = 77								

4.1. Assessment of Rapid Upper Limb Assessment

Based on the analysis of workers' posture using the Rapid Upper Limb Assessment (RULA) method with the ergo Fellow software, the grand score from the posture assessment is as follows:

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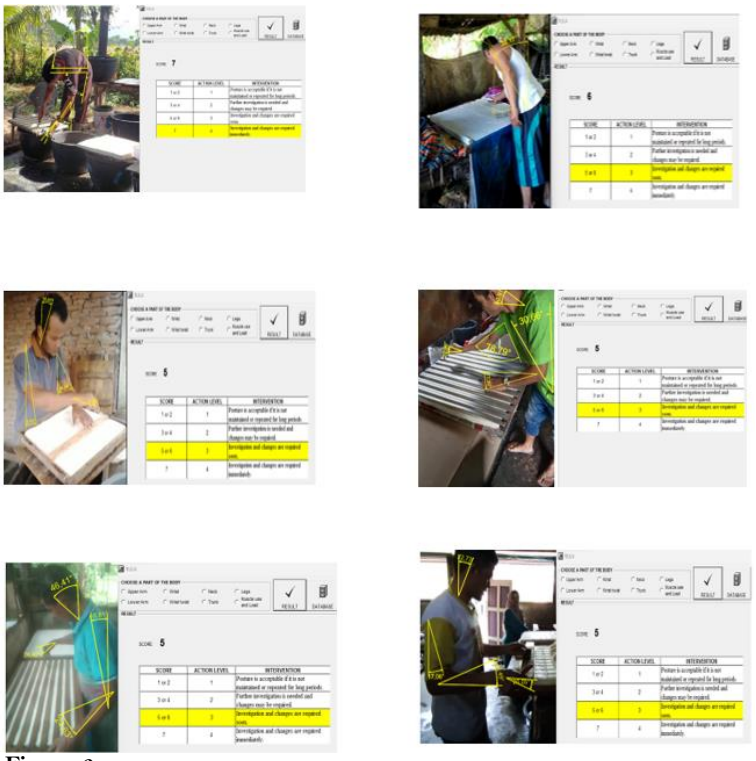

Figure 2.
Assessment of workers.

Table 2.
Recapitulation of MSMEs RULA score.

No	MSMEs	Grand score	Level	Action level	Action
1	TSH	7	Very high risk	4	Investigation and changes are required immediately
2	MG	6	High risk	3	Further investigation is needed
3	UTZ	5	High risk	3	Further investigation is needed
4	MT	5	High risk	3	Further investigation is needed
5	DOI	5	High risk	3	Further investigation is needed
6	ATU	5	High risk	3	Further investigation is needed

Based on the recapitulation results in the table above, it shows that out of the six tofu MSMEs analyzed, one tofu MSMEs received a grand score of 7, meaning immediate improvement is necessary, one SME received a score of 6, indicating that improvement is needed in the near future, while the other four tofu SMEs received a grand score of 5, which is at action level 3. In general, the level of MSDs risk is high risk. Based on the results obtained, the next step is to design cutting tools to anticipate MSDs risks for workers.

5. Discussion

5.1. Anthropometry

Anthropometric calculations are performed to determine the size, shape, and dimensions of the tool to be designed, so that it fits the physical characteristics of the tool's users and adheres to ergonomic principles. The anthropometric data that will be used includes standing height (TTB), hip height (TP), and standing horizontal reach. (JHB).

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Table 3.
Workers anthropometry.

Worker	Part of body		
	TTB	TP	JHB
1	168	87	69
2	173	90	71
3	170	89	71
4	180	96	75
5	165	87	69
6	177	94	74
7	160	83	66
8	175	92	74
9	177	94	74
10	176	96	75
11	174	91	71
12	160	83	66
13	175	92	74
14	160	83	66
15	175	92	74
16	176	96	75
17	165	87	69
18	170	89	71
19	160	83	66
20	170	89	71
21	162	87	68
Average	170.3	89.4	70.9

5.2. Design of Cutting Tool

We have conducted research and processed technical data using the workers' body measurements and anthropometric calculations. Therefore, the tofu cutting tool will be designed using anthropometric data at the 50th percentile. The tofu cutting tool's design will incorporate the following measurements:

1. Standing Height (SH)

The tofu cutting tool's design incorporates a standing height measurement to ensure the tool's height aligns with the user's height. We will use a height of 170.3 cm here.

2. Hip Height (HH)

We conduct this measurement to ensure the tool's height aligns with the worker's hip height, thereby preventing the worker from bending over. We will use 89.4 cm as the measurement.

3. Standing Horizontal Reach (SHR)

We measure the forward arm reach to match the worker's arm reach, which is 70.9 cm. We will design the tool using the results of the anthropometric measurements, hoping it will adhere to ergonomic principles and lower the risk of MSDs. We will design the tool using stainless steel material.

The design of the tool that has been adjusted to the anthropometric measurements of the workers can be seen in Figure 3 as follows:

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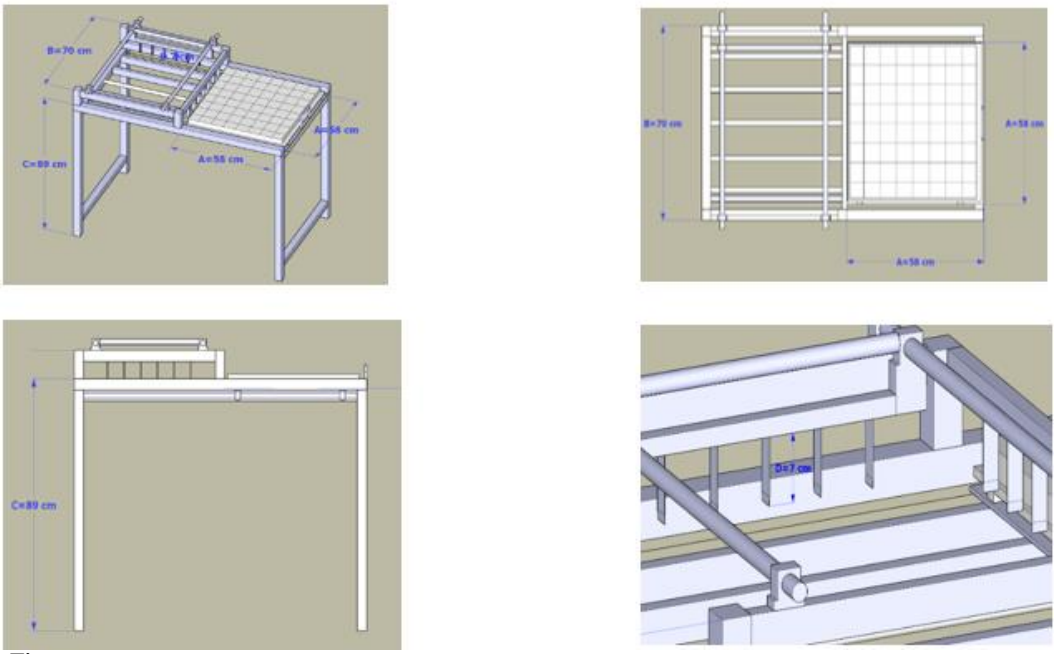

Figure 3.
Design of Tofu cutting tools.

5.3. Simulation Results of Proposed Design Comparison

The results of the proposed design comparison simulation conducted using Catia V5 software can be seen in the following figure:

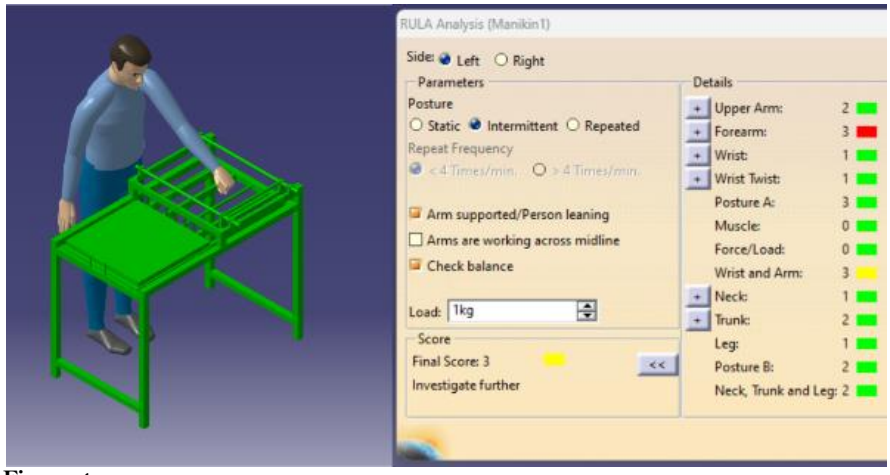

Figure 4.
Simulation results of proposed design comparison.

Based on the results of the Rapid Upper Limb Assessment analysis conducted on the design using Catia V5 software, it shows a grand score of 3, which means it is at a moderate level. There has been a decrease in the level of MSD risk from initially very high and high to moderate.

The RULA method analysis results reveal differences between the knife and ruler cutting methods and the proposed tofu cutting tool. By using the proposed tofu cutting tool, the workers' posture no longer forms an unergonomic posture.

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6. Conclusion

According to the posture assessment results of workers involved in the tofu cutting process at MSMEs in Aceh, among the six assessed MSMEs, one obtained a score of 7 (Very High), which requires immediate improvement; one SME scored 6 (High Risk), while the remaining four SMEs attained a score of 5 (High), indicating that immediate enhancements are essential. The results of the posture evaluation indicating a high-risk level provide an initial foundation for the development of new cutting tools.

The dimensions of the proposed tofu cutting tool are determined by the worker's body measurements to ensure ergonomic comfort during use. The proposed design for the tofu cutting tool includes a sliding mechanism and is constructed from stainless steel, enhancing the tool's durability. The simulation findings of this tool indicated a reduction in the risk level of MSDs from an initial score of 7 (very high) to 3 (medium). We anticipate that this tool will not only mitigate the risk of musculoskeletal disorders (MSDs) but also decrease the time required for tofu cutting, reduce repetitive motions, and yield more consistent tofu cuts.

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