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ERGONOMIC RISK AND PHYSICAL WORKLOAD ASSESSMENT IN SMALL-SCALE TOFU INDUSTRY: A CASE STUDY AT GANG KEDELAI RAYA TOFU PRODUCTION CENTER

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ABSTRACT. Many small-scale tofu industries still depend on manual production systems, which often require workers to perform repetitive movements, lift heavy loads, and maintain awkward postures for long periods. These conditions may increase the risk of musculoskeletal disorders and physical fatigue. This study aimed to assess musculoskeletal complaints, work posture risks, and physical workload among workers in small-scale tofu industries, and to develop an ergonomic improvement proposal for the existing production system. The study was conducted in five small-scale tofu industries in Cilegon City involving 13 workers engaged in main production activities, including soybean washing, grinding, boiling, filtering, pressing, cutting, and packaging. Musculoskeletal complaints were identified using the Nordic Body Map (NBM), posture risks were evaluated using the Rapid Upper Limb Assessment (RULA), and physical workload was measured based on Cardiovascular Load (%CVL). The NBM results indicated that workers commonly reported discomfort in the lower back, shoulders, arms, wrists, and legs. Several production activities showed high RULA scores of 6–7, particularly tasks involving bending, reaching, lifting, and repetitive upper-limb movements, indicating that corrective action was urgently needed. The mean %CVL was 37.15%, which falls into the moderate workload category. Based on these findings, a multi-level production floor was proposed as an ergonomic improvement to reduce excessive bending, manual lifting, and non-neutral working postures. The proposed design has not yet been implemented in the workplace; however, it was evaluated through posture reassessment, showing a potential reduction in RULA scores to 2–3 for all main activities. These results suggest that ergonomic redesign can improve worker safety and comfort while supporting more sustainable small-scale tofu industries.

INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) play an important role in Indonesia's economy, particularly through employment creation, local income generation, and the development of community-based production activities. In the food-processing sector, an important small-scale industry is the tofu industry, which processes soybeans (Glycine sp.) into an affordable source of plant-based protein for the community. The small-scale tofu industry contributes to food security, community nutrition, and income generation for local workers and business owners (Syaroh *et al*., 2021). In Cilegon City, Banten Province, this industry has developed as a home-based production activity with a relatively high production capacity. One of the production centers is located in Gang Kedelai Raya, Cibeber District, where five small-scale tofu industries operate. However, the home-based nature of these businesses often limits the application of modern production technology, structured work systems and ergonomic work facilities.

In addition to ergonomic limitations, previous studies have highlighted production-related challenges in small-scale tofu industries, including cleaner production opportunities, process efficiency, and quality improvement. Rani *et al*. (2022) discussed cleaner production opportunities in the tofu industry, Nurul *et al*. (2023) reviewed cleaner production

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practices in Indonesian small and medium tofu-processing enterprises, and Rina *et al*. (2023) examined quality improvement in tofu production processes using Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA). These studies indicate that small-scale tofu industries still face technical and operational limitations that may affect production sustainability.

Most small-scale tofu industries still rely on manual production processes, including soaking raw materials, grinding, boiling, filtering, seeding, molding, and cutting. At the Cilegon Tofu Company, these activities involve several problematic working conditions. During soaking, workers manually lift and transfer soybeans in a bent posture, thereby increasing the risk of lower back and shoulder pain. Grinding requires workers to bend while feeding soybeans into the machine and stand for long periods, which may cause fatigue in the lower back, neck, and shoulder. Boiling exposes workers to high temperatures, repetitive stirring, and manual handling of hot containers, leading to physical fatigue, arm strain, and heat stress. Filtering is particularly demanding because workers lift hot soybean pulp or liquid while bending and twisting their bodies, increasing the risk of discomfort in the shoulders, wrists, and back. Seeding, molding, and cutting also involve repetitive movements, awkward postures, and prolonged standing, which may contribute to discomfort in the hands, upper arms, wrists, and legs.

These conditions are consistent with previous studies showing that small and home-based industries often have limited ergonomic work facilities and weak implementation of occupational safety and health practices (Widodo *et al*., 2019; Irwanda and Nurmayanti, 2022). Ergonomic risks in tofu production have also been reported by Erliana *et al*. (2023) and Chalifatunnisa and Ramdhani (2025), while RULA has been widely used to assess postural risks in manual and food-processing activities (Mahmood *et al*., 2020; Temitayo *et al*., 2023; Wadhwa *et al*., 2022). In addition, a high physical workload has been associated with injury, fatigue, and discomfort, and combining posture assessment with workload analysis can provide a stronger basis for ergonomic improvement (Mura and Dini, 2023; Koeswara and Rahmah, 2025).

The empirical findings of this study strengthen the urgency of the problem. Several workstations recorded high RULA scores of 6–7, the average %CVL reached 37.15%, and NBM results showed that complaints were mainly concentrated in the lower back, waist, shoulders, wrists, and hands. Although previous ergonomic studies have examined musculoskeletal complaints, posture risk, and physical workload in food MSMEs and small-scale industries, many still analyze these aspects separately (Meenakshi *et al*., 2020). Therefore, this study extends previous research by integrating the Nordic Body Map, RULA, and %CVL to provide a more comprehensive assessment of ergonomic risk and physical workload in the small-scale tofu industry. This integrated approach is in line with Kalkis *et al*. (2021), Simon *et al*. (2024), and Manohar *et al*. (2025), who emphasized the importance of combining several ergonomic evaluation methods to improve the assessment accuracy and strengthen improvement recommendations.

The novelty of this study lies in its integrated ergonomic assessment of the small-scale tofu industry by combining the Nordic Body Map (NBM), Rapid Upper Limb Assessment (RULA), and Cardiovascular Load (%CVL) within a multiple-case study setting. Unlike previous studies that examined musculoskeletal complaints, posture risk, or physical workload separately, this study evaluated these three aspects simultaneously to provide a more comprehensive basis for work-system improvement. This integrated approach is expected to produce practical ergonomic recommendations that are suitable for the characteristics and limitations of small-scale tofu production industries.

Based on these research gaps, this study aimed to evaluate the ergonomic conditions and physical workload in five small-scale tofu industries located in a tofu industry in Cilegon, Banten Province. The evaluation was conducted by identifying musculoskeletal complaints using the Nordic Body Map, assessing work posture using RULA, and measuring physical workload using the %CVL. In addition, this study proposes an ergonomic work-system improvement to reduce posture risk and physical workload, improve worker safety and comfort, and support the operational sustainability of the small-scale tofu industry.

RESEARCH AND METHODS

Research Location and Object

Five small-scale tofu industries in Cilegon City, Banten Province, were selected as the subjects of this study. The location was selected because it represents a small-scale tofu industry center where production activities are predominantly performed using manual and traditional work systems. The main activities in tofu production, ranging from raw material processing to boiling, filtering, shaping, and cutting tofu, are

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included in the scope of this research. The work processes in these industries are generally characterized by repetitive physical activities, non-ergonomic work postures, and the use of simple equipment, as reported by Irwanda and Nurmayanti (2022) and Hidayatullah and Prasetyo (2023).

Research Workers

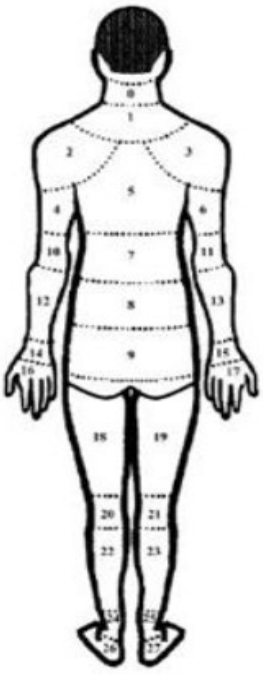
This study included 13 production workers from five small-scale tofu industries in Cilegon City, Banten Province. These workers are directly involved in daily operations. Some of the criteria that workers must meet include having at least one year of work experience, being physically healthy, and being consistent in performing their primary duties. A total sampling approach was used, where each MSMEs had a varying number of workers. Therefore, all workers who fulfilled the criteria were included in this study. Direct worker representation is important in conducting ergonomic risk assessments, which is in line with ergonomic research in small industries and MSMEs conducted by Mufti *et al*. (2019) and Widodo *et al*. (2019).

Data Collection and Analysis Methods

An integrated ergonomics method was used in this study. This study obtained a comprehensive picture of occupational risks, including musculoskeletal complaints, work posture risks, and physical workloads, through a combination of subjective and objective methods.

Nordic Body Map (NBM)

Musculoskeletal complaints among workers were identified using the Nordic Body Map (NBM) questionnaire. The NBM is commonly used in ergonomic studies to systematically describe the subjective discomfort experienced by workers in different body regions, particularly in small industries and manual work activities (Kuorinka *et al*., 1987; Prakoso *et al*., 2019). In this study, the questionnaire was completed by workers who indicated the level of discomfort experienced in several body parts, including the neck, shoulders, arms, elbows, wrists/hands, upper back, lower back, hips/buttocks, knees, and ankles/feet. These body regions were assessed using a human body map (Figure 1). Each response was converted into a score ranging from 1 to 4, where code A indicates no discomfort, code B indicates mild discomfort, code C indicates moderate discomfort, and code D indicates severe discomfort.



No	Location	Grade of complaints			
0	Pain/stiff in the upper neck	A	B	C	D
1	Pain in the lower neck				
2	Pain in the left shoulder				
3	Pain in the right shoulder				
4	Pain in the left upper arm				
5	Pain in the back				
6	Pain in the right upper arm				
7	Pain in the waist				
8	Pain in the buttock				
9	Pain in the bottom				
10	Pain in the left elbow				
11	Pain in the right elbow				
12	Pain in the left lower arm				
13	Pain in the right lower arm				
14	Pain in the left wrist				
15	Pain in the right wrist				
16	Pain in the left hand				
17	Pain in the right hand				
18	Pain in the left thigh				
19	Pain in the right thigh				
20	Pain in the left knee				
21	Pain in the right knee				
22	Pain in the left calf				
23	Pain in the right calf				
24	Pain in the left ankle				
25	Pain in the right ankle				
26	Pain in the left foot				
27	Pain in the right foot				

Figure 1. NBM questionnaire
(Sources: Kuorinka *et al.,* 1987)
A = no pain; B = some pain; C = pain; D = very painful.

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The total NBM score was used to determine the risk of musculoskeletal complaints. In general, lower total scores indicate a lower level of complaints, whereas higher total scores indicate greater musculoskeletal discomfort and a higher need for ergonomic interventions (Adiyanto *et al*., 2022).

Rapid Upper Limb Assessment (RULA)

Work posture risk was assessed using the Rapid Upper Limb Assessment (RULA) method. This method is used to evaluate work postures involving the upper arms, forearms, wrists, neck, trunk, and legs, particularly in activities that require static postures, repetitive movements or forceful exertion (McAtamney and Corlett, 1993). RULA scores were classified according to ergonomic risk levels to determine the urgency of corrective actions. The use of RULA in food industries and MSMEs has been widely applied in previous ergonomic studies (Mahmood *et al*., 2020; Wadhwa *et al*., 2022; Temitayo *et al*., 2023; and Hidayatuloh *et al*., 2022). The RULA assessment was conducted in three main stages, as described by McAtamney and Corlett (1993):

Step 1: Development of work posture recording

At this stage, the observed body segments were divided into two groups: Group A included the upper arm, forearm, and wrist, whereas Group B included the neck, trunk, and legs. This categorization ensures that all relevant postures are covered, including abnormal or restricted foot, upper body, or neck postures that may affect the upper arm posture and overall risk.

Step 2: Development of the assessment system

Group A was summarized into a single score in the posture assessment, while Group B assessed the posture of the neck, upper body, and legs to represent the operator's level of discomfort. Posture assessment was conducted using a nine-point scale, with a score of 1 indicating a posture with a low musculoskeletal load. In cases of differing assessments, the musculoskeletal load associated with each posture is discussed until an approved score is reached. The results were then summarized in posture assessment tables, known as posture score tables A and B.

Step 3: Development of the action level scale

The level of action was determined in the final stage based on the total score of the study results. According to Lynn, McAtamney, and Corlett, RULA action levels are classified into four categories: A detailed description of the four action levels is provided in Table 1.

Cardiovascular Load (%CVL)

Physical workload was assessed using the Cardiovascular Load (%CVL) method, which compares workers' heart rates during work with their resting and maximum heart rates. The heart rate during tofu production was measured using a heart rate monitor, and the resting heart rate was recorded before work activities began. The %CVL value was calculated using the following formula:

$$\%CVL = \frac{HR_{work} - HR_{rest}}{HR_{max} - HR_{rest}} x\ 100$$

Where HR_{work} is the working heart rate, HR_{rest} is the resting heart rate, and HR_{max} is the estimated maximum heart rate, calculated as 220 age. The resulting % CVL value was used to classify the physical workload level, with higher values indicating greater cardiovascular strain (Widodo *et al*., 2024; Koeswara and Rahmah 2025).

Data Processing Stages

The data processing stages in this study were conducted systematically as follows. First, the Nordic Body Map questionnaire data were analyzed to identify the body parts that were most likely to experience musculoskeletal complaints. Second, the RULA scores were calculated for each main work activity to determine the level of work posture risk.

Third, the Cardiovascular Load (%CVL) values were calculated to evaluate the workers' physical workload during production activities. Fourth, the results of the three methods were integrated to identify the work activities with the highest ergonomic risk. The final stage is the preparation of proposals for improvements to the work system based on the results of ergonomic evaluation.

RESULTS AND DISCUSSION

Nordic Body Map (NBM)

Thirteen workers completed the Nordic Body Map questionnaire: three from MSME 1, 3 MSME 2, three from MSME 3, and two each from MSME 4 and 5. Table 2 shows detailed data on these workers. Table 3 shows the results of the Nordic Body Map questionnaire distributed to the production department of five MSMEs located in Kedelai Raya Alley, Imam Bonjol Street, Cibeber District, Cilegon City.

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Table 1. RULA action level

Action Level	Score	The level of risk	Implication and risk posture employment issues
1	1 – 2	Posture accepted	Acceptable posture if it is not minted or repeated for long periods
2	3 – 4	Low risk	Needed further investigation and changes may be required
3	5 – 6	Intermediate risk	Needs further investigation and changes are required soon
4	7	Very high risk	Investigation and implement the necessary changes immediately

Table 2. Worker data in each MSME

No	Name	UMKM	Age	Length of work (years)	Job desk
1	Worker 1	1	38	4	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
2	Worker 2		54	3	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
3	Worker 3		21	2	Boiling well
4	Worker 4	2	40	4	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
5	Worker 5		51	2	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
6	Worker 6		23	2	Boiling well
7	Worker 7	3	33	5	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
8	Worker 8		36	4	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
9	Worker 9		28	4	Boiling well
10	Worker 10	4	24	2	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
11	Worker 11		23	4	Boiling well
12	Worker 12	5	34	2	Soaking, grinding, boiling, filtering, seeding, molding, temporary storage
13	Worker 13		35	6	Boiling well

Based on the Nordic Body Map questionnaire, musculoskeletal disorder (MSDs) complaint scores varied among workers. The highest score was reported by Worker 2 (65), followed by Worker 13 (57) and Worker 5 (56). In contrast, the lowest scores were observed for workers 11 (35) and 3 (38). The overall mean score was 49.69, indicating that MSD complaints were prevalent among the respondents.

The distribution of complaints by body region showed that the trunk was the most commonly affected area. The highest total scores were found for the back and waist, each reaching 37, indicating that these areas were the main sources of discomfort. Complaints in the left and right shoulders were also relatively high, with a total score of 32 for each side. In addition, complaints in the upper arms remained noticeable, with a total score of 29 on both sides, suggesting frequent upper limb involvement during production activities.

Complaints regarding the distal upper extremities were also observed. The right wrist had a total score of 28, the left wrist 27, and both hands 26. Moderate complaints in the forearms may be associated with repetitive manual tasks, tool use, and prolonged non-neutral wrist position. In contrast, complaints in the lower extremities were relatively low. Both thighs and ankles each recorded a total score of 16, whereas the feet recorded a score of 17. This pattern suggests that the physical workload was mainly concentrated in the trunk and upper limbs rather than the lower limbs of the body.

Across the five MSME locations, MSME 5 recorded the highest average complaint score of 55.50, followed by MSME 1 at 51.67, MSME 3 at 50.67, and MSME 2 at 50.33.

Table 3. Results of the nordic body map questionnaire

Location	Workers													Total Parts
	UMKM 1			UMKM 2			UMKM 3			UMKM 4		UMKM 5		
	1	2	3	4	5	6	7	8	9	10	11	12	13	
Pain/stiff in the upper neck	1	2	1	2	1	1	1	2	1	1	1	1	2	17
Pain in the lowe neck	1	2	1	1	1	1	1	2	1	1	1	1	2	16
Pain in the left shoulder	3	3	3	3	2	2	2	3	2	2	1	3	3	32
Pain in the right shoulder	3	3	3	3	2	2	2	3	2	2	1	3	3	32
Pain in the left upper arm	2	2	2	2	3	2	2	3	2	2	1	3	3	29
Pain in the back	3	4	1	3	3	3	4	3	3	3	1	3	3	37
Pain in the right upper arm	2	2	2	2	3	2	2	3	2	2	1	3	3	29
Pain in the waist	3	3	1	4	3	1	4	4	3	3	3	3	2	37
Pain in the buttock	2	2	1	1	1	1	1	1	2	1	3	1	1	18
Pain in the bottom	1	2	1	2	1	1	1	1	1	1	2	1	1	16
Pain in the left elbow	2	2	2	1	3	1	2	2	1	1	1	3	2	23
Pain in the right elbow	2	3	2	1	3	1	2	2	1	1	1	3	2	24
Pain in the left lower arm	2	2	2	2	3	1	2	2	2	2	1	2	2	25
Pain in the right lower arm	2	3	2	2	3	1	2	2	2	2	1	2	2	26
Pain in the left wrist	2	3	1	3	3	2	2	3	1	2	2	2	1	27
Pain in the right wrist	3	3	1	3	3	2	2	3	1	2	2	2	1	28
Pain in the left hand	3	2	1	1	2	2	2	3	3	2	1	2	2	26
Pain in the right hand	3	2	1	1	2	2	2	3	3	2	1	2	2	26
Pain in the left thigh	1	2	1	2	1	1	1	1	1	1	1	2	1	16
Pain in the right thigh	1	2	1	2	1	1	1	1	1	1	1	2	1	16
Pain in the left knee	1	2	1	2	2	1	2	1	1	1	1	1	2	18
Pain in the right knee	1	2	1	2	2	1	2	1	1	1	1	1	2	18
Pain in the left calf	2	2	1	2	2	2	1	1	2	1	1	2	3	22
Pain in the right calf	2	2	1	2	2	2	1	1	2	1	1	2	3	22
Pain in the left ankle	1	2	1	2	1	1	1	1	1	1	1	1	2	16
Pain in the right ankle	1	2	1	2	1	1	1	1	1	1	1	1	2	16
Pain in the left foot	1	2	1	1	1	1	2	1	2	1	1	1	2	17
Pain in the right foot	1	2	1	1	1	1	2	1	2	1	1	1	2	17
Individual scores	52	65	38	55	56	40	50	55	47	42	35	54	57	
Average MSMEs	51.67			50.33			50.67			38.5		55.5		
Average Total	49.69													

The lowest average score was found for MSME 4, with a score of 38.50. These differences may reflect variations in task characteristics, workload intensity, workstation design, and work posture at different production sites. Overall, the NBM results indicate that MSD complaints among workers were mainly concentrated in the back, waist, and shoulders, followed by the wrists and hands. This distribution suggests potential ergonomic risks associated with awkward or prolonged working postures, repetitive upper-limb movements, and uneven task demands. As the upper body was frequently involved in production activities, further postural assessment was conducted using the Rapid Upper Limb Assessment (RULA) method during the soaking, grinding, boiling, filtering, and molding processes.

Rapid Upper Limb Assessment (RULA)

The RULA assessment results demonstrated a clear improvement in the posture of workers at all five workstations after the ergonomic intervention was implemented. RULA values ranging from 6 to 7 recorded on the right and left sides of the body before the intervention reflected a high to very high level of ergonomic risk. Based on the scores, workers experience awkward postures, repetitive manual handling, and excessive trunk flexion, factors widely associated with work-related disorders (WMSDs) in manual production settings (Rani *et al*., 2021).

After ergonomic improvement was proposed, a posture reassessment was conducted to estimate its potential effect on ergonomic risk. The reassessment results showed that the RULA scores decreased

consistently to a range of 2–3 across all workstations. This reduction indicates a shift toward lower-risk and more acceptable working postures, where immediate corrective action is generally unnecessary. The most notable improvements were observed at workstations involving lifting and material transfer, particularly during boiling, filtering, and molding, which initially showed the highest RULA scores. Adjustments to workstation height, reach distance, and material handling methods contributed to lower posture risk and physical workload, as reported in previous ergonomic intervention studies (Hosseini *et al*., 2022; González-Alonso *et al*., 2023). The comparison of work posture scores during tofu production activities with hazardous posture risks is presented in the following table.

Overall, ergonomic interventions, even relatively simple ones, have been shown to significantly reduce postural risks in small-scale food processing activities. The effectiveness of ergonomic design in minimizing musculoskeletal strain and improving work sustainability was demonstrated by a consistent decrease in RULA scores across all workstations. RULA remains effective as a posture-based assessment tool for evaluating and improving manual work systems, especially in small and medium-sized enterprises (SMEs), as this is in line with the latest ergonomic studies (David and Buckle, 2020; Rahmawati and Prasetyo, 2024).

Cardiovascular Load (%CVL)

A total of 13 workers from five small- and medium-sized tofu processing businesses were involved in assessing the physical workload using %CVL. These workers varied in age and environments. The %CVL results generally ranged between 30% and 48%, indicating that most workers experienced a moderate physical workload. Based on the interpretation of the %CVL value, values below 30% were classified as light, 30–60% as moderate workload, and above 60% as excessive physical strain. In this study, most workers had a moderate physical workload, reflecting that although work activities in small- and medium-sized tofu businesses trigger physiological demands, they are manageable for workers.

The results show that workers from MSMEs 1 and 2 have the highest average %CVL values, both exceeding 37% when analyzed based on MSME groups. Workers aged > 50 years predominantly contributed to these findings, as they exhibited higher working heart rates and reduced maximal heart rate capacity associated with age-related physiological changes. These results highlight that age has a significant impact on cardiovascular load, even when performing the same tasks. Older workers tend to experience relatively higher cardiovascular stress than younger workers, even when faced with the same physical demands, as emphasized in recent ergonomic studies (Basahel, (2021); Hermawati *et al*., 2023) and consistent with the findings of this study.

In contrast, the average %CVL value was generally slightly lower, mostly approaching the lower limit of the moderate workload category for workers from MSMEs 3, 4, and 5. These results indicate better work tolerance, possibly supported by a younger age profile and a more stable work rhythm.

Tabel 4. Comparison of work posture scores before and after improvement

No	Activities	Before		After	
		Right	Left	Right	Left
1	**Soaking Process**				
	The soaked soybeans are poured into the drain pan	6	6	3	3
2	**Milling Setup**				
	The soaked soybeans are transported to the milling machine	6	6	3	3
3	**Boiling Setup**				
	The ground soybeans are transported to the boiling pan	7	7	3	2
4	**Filtering Setup**				
	The boiled soybeans are transported from the boiling pan to the filtering container	7	7	3	2
5	**Molding Setup**				
	The seeded soybeans are transported from the filtering container to the molding container	7	7	3	2

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However, a %CVL value consistently exceeding 30% indicates that the work still requires sustained physical effort and should not be considered light. Long-term exposure to moderate cardiovascular stress, especially in small-scale food processing industries, can contribute to cumulative fatigue and decreased work endurance if not accompanied by adequate rest or ergonomic improvements, as shown by recent studies (Zakerian *et al*., 2020; Putri and Nurmianto 2024). Therefore, interventions such as job rotation, rest scheduling, and ergonomic design remain important for maintaining the long-term health and productivity of workers, even though the workload is still within acceptable limits.

The integrated analysis of NBM, RULA, and %CVL showed a consistent relationship between musculoskeletal complaints, postural risk, and physical workload in small-scale tofu production. The NBM results showed that the highest complaints occurred in the waist at 84.62%, followed by the right shoulder and back at 76.92% and the left shoulder at 69.23%. These complaints were in line with the RULA results, which showed moderate to very high ergonomic risks in activities involving bending, lifting, reaching and material transfer. The %CVL results also supported this pattern, with an average value of 34.47%, indicating that the workers experienced a moderate physical workload. This finding confirms that repeated bending and manual material handling without assistive devices may increase lower back and shoulder complaints, as explained by Tarwaka *et al*. (2015). This also supports McAtamney and Corlett (1993), who stated that high RULA scores indicate the need for workstation redesign, and Kroemer and Grandjean (2000), who emphasized that %CVL values above 30% require workload improvement.

The relationship between NBM, RULA, and %CVL can be clearly seen in several main job tasks. In the grinding task, workers often bent their bodies while feeding soybeans into the machine and pushing materials manually, causing dominant complaints in the shoulders and back, RULA scores of 5–6, and estimated %CVL values of 33–35%. In the filtering task, workers lifted hot soybean pulp or liquid while bending and twisting their bodies, resulting in complaints in the waist, shoulder, and wrist, with a RULA score of 6 and %CVL values of 35–37%. The molding task showed the highest ergonomic risk, with a RULA score of 7, dominant complaints in the waist, shoulders, and upper arms, and %CVL values of 36–37%. Meanwhile, the cutting task involved repetitive hand movements and static standing, causing wrist and arm complaints, with RULA scores of 4–5 and %CVL values of 31–33. These findings show that higher RULA scores tend to be followed by higher NBM complaints and higher %CVL values, especially for physically demanding tasks. Compared with previous studies, this study extends the findings of Erliana *et al*. (2023), Chalifatunnisa and Ramdhani (2025), and Widodo *et al*. (2024) by linking subjective complaints, postural risk, and physiological workload in one integrated analysis.

Based on these findings, ergonomic improvements should be tailored to each job task. Soaking requires trolleys and a higher soaking tank to reduce bending and manual lifting efforts. Grinding requires the adjustment of the machine hopper height and the use of anti-fatigue mats. Boiling requires long-handled stirring tools, heat-resistant gloves, and good ventilation. Filtering requires a semi-mechanical filtering device, a 90 cm worktable, and shorter material transfer distances. Seeding requires ergonomic stirring tools and sit-stand support. Molding should be prioritized by providing an ergonomic molding table, manual or hydraulic pressing system, and sliding racks. Cutting requires ergonomic knives, a 90 cm cutting table, and job rotation to avoid repetitive movements. These recommendations are consistent with studies showing that workstation redesign, assistive tools, and improved work methods can reduce postural risk, physical workload, and musculoskeletal strain (Kroemer and Grandjean, 2000; Hermawati *et al*., 2023; Hosseini *et al*., 2022; Rahmawati and Prasetyo, 2024).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study shows that the work system in small-scale tofu industries is still dominated by manual activities that expose workers to ergonomic risks and moderate physical workloads. The Nordic Body Map results indicated that musculoskeletal complaints were mainly concentrated in the lower back, waist, shoulder, and upper arms. The RULA assessment showed that several main workstations required corrective action owing to awkward postures, repetitive movements, and manual material handling. In addition, the %CVL results confirmed that tofu production involves sustained physical effort, which may lead to fatigue if not appropriately managed.

The proposed ergonomic improvement, particularly the multilevel production floor and work layout adjustment, showed a potential reduction in posture risk based on the reassessment results. These findings

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suggest that simple, field-based ergonomic improvements can help improve work posture, reduce musculoskeletal strain, and enhance worker comfort without requiring major technological investment. However, this study had several limitations. The sample was limited to 13 respondents from five small-scale tofu industries in one area; therefore, the generalization of the findings remains limited. In addition, the measurements were conducted using a cross-sectional approach and did not evaluate the long-term effects of ergonomic interventions. Overall, ergonomic redesign remains important for supporting safer, healthier, and more sustainable work practices in small-scale tofu industries.

Recommendations

Future research is recommended to expand the scope of study locations and increase the number of small-scale tofu industries to obtain a more representative picture of ergonomic risks. Further studies should integrate ergonomic assessment with productivity, cycle time, and energy efficiency analyses to evaluate the impact of ergonomic interventions more comprehensively. In addition, the accuracy of work posture assessment can be improved by using application-based ergonomic technologies such as simple motion capture or biomechanical analysis. Future research is expected to contribute to the development of sustainable applied ergonomics models in small-scale agro-food industries.

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