Ergonomic Assessment of Manual Material Handling Workers In The Semarang Tofu Industry Utilizing SNI 9011:2021

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Abstract

In order to produce delectable, nutritious and affordable pricing, tofu products go through a labor-intensive manufacturing process that demands physical exertion and muscular vigor. In Indonesia, particularly in Semarang, Central Java, the tofu manufacturing process is still carried out manually, including the handling of raw soybeans and finished tofu, generally called Manual Material Handling (MMH). Among the tasks performed by MMH workers include lifting soybean, holding soybean extraction, lifting and carrying tofu barrels. Lifting loads range from 10 to 70 kg. The objective of this paper is to assess the degree of ergonomic risks and complains among MMH workers. The method used is quantitative analysis with a cross-sectional research design that refers to SNI 9011: 2021. Research methods to collect data include observations, interviews, and surveys. 80% of respondents complained of experiencing pain. Painful body parts with a high level of frequency and severity are located in the neck, right shoulder, upper back, lower back, arm, and right hand. A score of 9 indicates a high-risk level for MSD concerns. The total score of potential ergonomic risks is in the range of 11–19, with body scores vary from 2 and 8, material handling scores is 8. In order to reduce the risk of ergonomic hazards in MMH activities, risk control efforts are carried out by dividing the load into acceptable limits, lifting loads balance on both sides of the body. Providing assisting devices, such as ergonomic hand trolleys, can handle huge amounts with fewer frequent material handlings. Counseling is carried out for workers to help them because more aware and knowledgeable about how to conduct MMH activities safely.

Keywords: manual material handling, ergonomic risk level, SNI 9011:2021

INTRODUCTION

The processed soy product known as tofu is highly well-liked in Indonesia and throughout the world. It tastes savory flavor and delicious. In addition to having a pleasant flavor, tofu is healthy due to its high content of vegetable proteins (Gandhi, 2009; Rhoman and Budiretnani, 2018). Tofu is renowned for its affordability for people with low or limited economic, and the manufacturing of high-quality tofu entails multiple steps (Tandian and Praptininingsih, 2013). Tofu is still generally made in a traditional way; the equipment utilized is largely manual and relies more on human work. According to observations and several pieces of literature (Rhoman and Budiretnani, 2018; Tandian and Praptininingsih, 2013; Zheng et al., 2020) soybean selecting, cleaning, soaking, grinding, boiling, filtering, coagulant utilizing, pressing, cutting, and tofu packaging. There are numerous tasks that fall under the category of manual material handling (MMH) in the traditional and low-tech method of producing tofu. According to several research on occupational practice explain that MMH is related to the development of musculoskeletal disorders/MSDs (Johnen et al., 2022; Sarkar et al., 2016;

Abdullah and Dawal, 2020; Soleman and Priyadi, 2020; Purnomo, 2004). The incorrect working position can result in MSD symptoms or complaints (Abdullah and Dawal, 2020), and MMH activities have a high likelihood of causing improper work posture.

In the Cinde District of Semarang City, there is tofu industry center called Mrican Tofu Center, where there are six small-scale tofu industries. In Semarang, one of tofu industry is the Pak Parto's Tofu, which still uses manual for its production process. The main problem in production activities or processes is the movement of material from one level to the next production level (Negara *et al.*, 2021). However, manual material handling has a significant impact on worker's health, particularly when this activity is carried out repeatedly and for an extended period of time. Additionally, all activities in the tofu industry include various kinds of potential hazards, including work space, machinery, temperature, and light (Negara *et al.*, 2021).

Several studies have conducted ergonomic assessments using various methods, such as Maximum Permissible Limits (Soleman and Priyadi, 2021; Purnomo, 2004; Permenaker RI No 5 tahun 2018) Recommended Weight Limit (Soleman and Priyadi, 2021; Purnomo, 2004; Permenaker RI No 5 tahun 2018), Ovako Work Posture Analysis System / OWAS (Budianto, Prasetio and KN, 2020; Zhia and Sari, 2020; Pratiwi, 2012; Joshi and Deshpande 2019); Rapid Upper Limb Assessment (Pratiwi, 2012; Joshi and Deshpande, 2019); Rapid Entire Body Assessment (Pratiwi, 2012; Joshi and Deshpande, 2019); Amalia, Tjahyono, Jazuli, and Syamwil, 2021); Quick Exposure Check (Pratiwi, 2012, Joshi and Deshpande, 2019); Job Strain Index (Joshi and Deshpande, 2019); Manual Task Risk Assessment / ManTRA (Salsabila, 2019). The National Standards Agency, in Indonesia called Badan Standarisasi Nasional (BSN), on behalf of the government, published guidelines for ergonomic assessment in 2021, specifically SNI 9011:2021 regarding the measurement and evaluation of potential ergonomic hazards in the workplace (BSI, 2021). This standard was created to provide guidelines for ergonomic measures for Indonesia's industrial sector. Therefore, this study aims to assess degree of ergonomic potential hazards as an ergonomic assessment among MMH workers in order to prevent MSDs.

METHOD

Tofu industry that already exist are typically small-scale home industry. The object of observation in this article is one of the SMEs at the Mrican Tofu Centre, namely Pak Parto Tofu. The method used is quantitative analyses with a cross-sectional research design refers to SNI 9011:2021. A cross-sectional study is defined as observational research that analyzes variable data collected at a specific point in time across a sample population or a predetermined subset. It seeks to explain broad connection between components and situations (Hunziker and Blankenagel, 2021). Research methods to collect data include observations using video documentation, interviews, and surveys. The variables studied were symptom / complaints of MSDs and work posture among MMH worker.

The survey was carried out in reference to SNI 9011:2021, a survey of work-related musculoskeletal disorders (WMSDs), in Indonesia called Gotrak. Tofu industry's workers were surveyed, their responses were examined, and then continued to check the list of ergonomic potential hazards. Examining ergonomic risks based on activities with high incidence of MSD's symptom.

RESULTS AND DISCUSSION

Manual Material Handling (MMH) is a science and an art that involves handling, transferring / moving, packaging, storing, and supervision (controlling) of materials while

maintaining their shape. According to Ministerial Regulation No. 5 of 2018, manual handling is defined as repetitive manual lifting within one working day. MMH activities for the Occupational Safety and Health Administration (OSHA) are classified into Lifting / lowering; Push/pull, twisting, carrying, and holding (Soleman and Priyadi, 2021; Purnomo, 2004). Nowadays, several modern industries have made extensive use of machines to aid materials handling (Asshidiq and Nur Rahman As'ad, 2023), although MMH activities are still frequently found for the small-scale industries with limited space and low investment. The entire process of making tofu is carried out manually, hence the work falls under the MMH category. The MMH activities selection who were asked to filled out a survey.

SNI 9011:2021 is a national standard that contains recommended limit for manual lifting of loads and work risks (BSN, 2021; Asshidiq and As'ad, 2023). SNI 9011:2021 specifies that job selection is based on a relatively high prevalence of complaints concerning body parts before undertaking the MSDs complaint survey. The MMH activities consisted of ten MMH workers who were responded to a survey. Each worker has their own roles and responsibilities, as seen in Table 1.

Table 1
Tofu's Workers

Workers	Age (years old)	Working period (year)	Activities
W1	28	< 1	Handling (picking and lifting) of soybean material from warehouse to washing area
W2	29	5 – 10	Washing and grinding the soybeans
W3	30	>10	Tofu Molding and Pressing
W4	27	1 – 5	Arrangement into tofu barrels
W5	28	5 – 10	Lifting the ground soybeans to the boiling area
W6	31	>10	Filtering and lifting soybean extraction
W7	45	> 10	Tofu pressing and lifting soybean extraction
W8	27	1 – 5	Lifting and carrying tofu barrels
W9	43	> 10	Filtering and lifting soybean extraction toward cutting area
W10	31	1 – 5	Lifting and carrying tofu barrels

Tofu workers were given a questionnaire for the initial identification of fatigue (Image 1) and pain experienced (Image 2). Workers and the workplace might be impacted by improper manual handling (Irhamna and Herbawani, 2021). As results, with 30% of workers reporting often experience physical fatigue, and 70% of workers occasionally experience physical fatigue. MMH tofu's workers are more prone to experience physical exhaustion because of the high levels of physical activity they engage in with the task done manually. Pain and discomfort are the results of muscle exhaustion. Based on the results of pain measurement (Figure 2), 90% workers feeling pain or discomfort in a year. Workers with working periods longer than a year complained of pain, those with shorter working periods did not report any discomfort problems. In line with (Irhamna and Herbawani, 2021), which shows a connection between work experience and MSD complaints. The working period is the consequence of a worker's accumulation of work activities over an extended period of time.
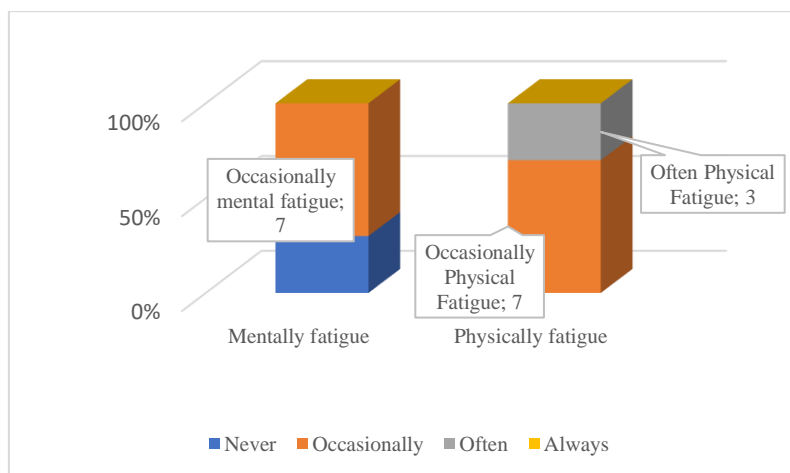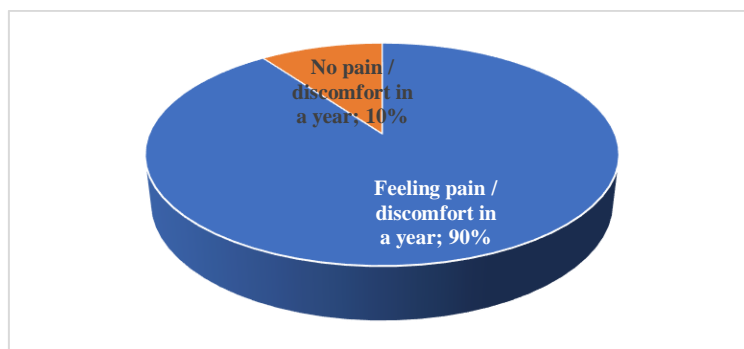
Image 1. Worker Fatigue

Image 2. Worker's Experience of Pain in A Year

Several studies to determine musculoskeletal symptoms or complaints frequently use The Nordic Questionnaires (Sarkar *et al.*, 2016; Soleman and Priyadi, 2021; Purnomo, 2004; Amalia, *et al*., 2021) or A Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) (Abdullah and Dawal, 2020). In SNI 9011:2021, a questionnaire is provided to identify complaints of work-related musculoskeletal disorders / WMSDs (called Gotrak) in workers and to determine which workplaces require evaluation. MSD is a complaint or pain due to injury and disorders of muscles, tendons, joints, nerves, and other soft tissues. The Nordic Questionnaire and WMSDs SNI 9011:2021 differ in that the former measures frequency and severity in greater detail, whereas the Nordic just measures severity of pain. While CMDQ is similar to WMSDs SNI 9011:2021, it differs slightly in the body subject and the severity level as well as interfere with work. Table 2 shows the results of the WMSD questionnaire of SNI 9011:2021.

According to the findings of the aforementioned complaints, certain body parts pose medium and high risk of ergonomic hazards. The medium risk is in the neck (worker 8th); Shoulder (workers 3rd, 6th, 8th, 10th); Upper back (workers 3rd, 6th, 7th, 8th); Arm (workers 5th, 9th); Lower back (workers 3rd, 7th, 8th); Hand (workers 6th, 7yh, 8th, 9th, 9th, 10th); Thigh (workers 7th, 9th); Knee (workers 3rd, 9th, 10th); Calf (7th, 9th, 10th); Leg (workers 7th, 9th). Whilst the high risk is in the neck (workers 9th, 10th); Shoulder (workers 7th, 9th); Upper back (workers 9th, 10th); Arm (workers 6th, 7th); Lower back (workers 6th, 9th, 10th); and Hand (worker 9th). Based on symptoms or complaints with high risk, there are several activities that experience pain and occur often (Table 3).

Table 2
Tabulation of WMSDs Symptom Data Utilizing SNI 9011:2021

Body Subject		Worker									
		1	2	3	4	5	6	7	8	9	10
Neck	Freq	1	1	2	2	2	2	2	2	3	3
	Sev	1	1	2	2	2	2	2	3	3	3
	Risk	1	1	4	4	4	4	4	6	9	9
Shoulder	Freq	2*	1	2**	2*	2*	2*	3**	3**	3*	2*
	Sev	2*	1	3**	1	2*	3*	3**	2**	3*	3*
	Risk	4	1	6	2	4	6	9	6	9	6
Elbow	Freq	1	1	2**	1	1	2**	2**	2**	2*	2*
	Sev	1	1	2**	1	1	2**	2**	1	2*	2*
	Risk	1	1	4	1	1	4	4	2	4	4
Upper Back	Freq	2	1	2	2	2	2	2	2	3	3
	Sev	2	1	3	1	2	3	3	3	3	3
	Risk	4	1	6	2	4	6	6	6	9	9
Arm	Freq	1	1	2*	1	2**	3**	3*	2*	2*	2*
	Sev	2*	1	2*	1	3**	3**	3*	2*	3*	2*
	Risk	2	1	4	1	6	9	9	4	6	4
Lower Back	Freq	1	1	3	2	2	3	3	3	3	3
	Sev	1	1	2	1	2	3	2	2	3	3
	Risk	1	1	6	2	4	9	6	6	9	9
Hand	Freq	1	1	1	1	2**	2**	2**	2*	3*	3*
	Sev	1	1	2**	1	1	3**	3**	3*	3*	2*
	Risk	1	1	2	1	2	6	6	6	9	6
Hip	Freq	1	1	1	1	2**	2**	2**	2**	2**	2**
	Sev	1	1	1	1	1	1	2**	2**	2**	2**
	Risk	1	1	1	1	2	2	4	4	4	4
Thigh	Freq	1	1	1	1	1	2**	2**	2*	2*	2*
	Sev	1	1	1	1	1	2**	3**	2*	3*	2*
	Risk	1	1	1	1	1	4	6	4	6	4
Knee	Freq	1	1	3**	2**	2**	2**	2**	2**	2*	3**
	Sev	1	1	2**	1	1	2**	2**	2**	3*	2**
	Risk	1	1	6	2	2	4	4	4	6	6
Calf	Freq	1	1	2**	1	1	1	2*	2*	3**	3**
	Sev	1	1	2**	1	1	1	3*	2*	2**	2**
	Risk	1	1	4	1	1	1	6	4	6	6
Leg	Freq	1	1	1	1	1	2**	2**	2**	2**	2**
	Sev	1	1	1	1	1	2**	3**	2**	3**	2**
	Risk	1	1	1	1	1	4	6	4	6	4

* one bodily part (right or left)
** two bodily parts (right and left)

Table 3
Work Releated MSDs Symptom

Complaints of high-risk body subject	Severity	Frequency	Work-related complaints
Neck	Pain	Often	Filtering and lifting soybean extraction Lifting and carrying tofu barrels
*Shoulder	Pain	Often	Lifting soybean extraction in pail

			Filtering and lifting soybean extraction
Upper Back	Pain	Often	Filtering and lifting soybean extraction Lifting and carrying tofu barrels
Arm	Pain	Often	Lifting soybean extraction in pail Tofu Molding and Pressing
Lower Back	Pain	Often	Filtering and lifting soybean extraction Lifting and carrying tofu barrels Tofu Molding and Pressing
*Hand	Pain	Often	Filtering and lifting soybean extraction

Table 4
Ergonomic Hazards Measurement of MMH Tofu Worker

No	Risk Factors / Hazards Category	Work / Activities			
		Lifting soybean extraction in pail	Filtering and lifting soybean extraction	Lifting and Carrying Tofu Barrels	Tofu Molding and Pressing
1-16	Upper Body	Hand force (1)	Shoulder (2); Wrist (1)	Shoulder (1)	Rapid Forearm (2)
		Contact Stress (2)	Contact Stress (1); Rapid Forearm (1)	Contact Stress (0)	Hand Force (1)
		Lighting (1)	Lighting (1)	Lighting (1)	Lighting (1)
		Temperatures (1)	Temperatures (1)	Temperatures (1)	Temperatures (1)
17-32	Back and Lower Extremity	Awkward Postures (0)	Awkward Postures (2)	Push / Pull (1)	Awkward Posture (3)
		Push / Pull (1)	Push / Pull (1)		Push/Pull (2)
33-44	Manual Handling	Weight Lifted (5)	Weight Lifted (3)	Weight Lifted (5)	Weight Lifted (3)
		Other Risk Factors (3)	Other Risk Factors (5)	Other Risk Factors (3)	Other Risk Factors (5)

The next step is to assess any potential risks associated with ergonomic issues (BSN, 2021; Asshidiq and As'ad, 2023; Wahyu *et al*., 2023; Denny and Radianto, 2023; Susanto *et al*., 2022). Measure the length of exposure – specifically, the duration the worker carries out the potential hazard in each job. The possible hazards for ergonomic issues among MMH Tofu worker is calculated in Table 4.

A score $\geq$ 7 indicates a risk of hazardous work, according to SNI 9011:2021 (BSN, 2021; Asshidiq and As'ad, 2023; Wahyu *et al*., 2023; Susanto *et al*., 2022). The weight lifted affects activities (a), (b), (c), and (d), which are considered to be high risk. The exposure duration of activity (a) reached 75.6%. The weight lifted by activity (a) is 35 kg per lift, moreover the movement of carrying the load rests on one hand.

Table 5
Summary of Potential Ergonomic Hazards Results

No	Activities	Ergonomic Hazard Score			Total Score	Result Interpretation
		Upper Extremity	Back and Lower Extremity	Manual Handling		
a	Lifting and carrying soybean extraction inz pail	5	1	8	14	Hazardous
b	Filtering and lifting soybean extraction	8	3	8	19	Hazardous
c	Lifting and carrying tofu barrels	2	1	8	11	Hazardous
d	Tofu molding and Pressing	5	5	8	18	Hazardous

The weight lifted in activity (b): soybean extraction uses large ladle tools weighing around 5 kg with one hand, and the distance from the body is quite far due to the hot material. It is in a caution zone. In activity (b), lifting is done repetitively, with high frequency of around 5 lifts per minute. The exposure duration reached 70,05%. Activity (b) has a high score in the upper extremity, meaning that the arm or elbow is higher than the level of stomach. To release soybean extract, both arms are squeeze. Activity worker (b) is the only person in the filtering workstation. He works seven working days a week without taking any breaks.

The tofu barrels in activity (c) holds about 70 kg. Two workers divide the load support duties since the lifting done by two people. However, it still exceeds the permitted force limit and is in hazardous category. Support for carrying the load is at the shoulder. Shoulder muscles may get sore as a result of this. Bursitis, tendinitis, rotator cuff tendinitis, and others.

Activity (d) is a tofu molding; there is an activity of lifting the mold with a load around 5 kg at a slightly loose distance from the body. Even though the loads did not carry over long distances, this activity is done repetitively, with lifting up to five times per minute. The body posture has been bent for a considerable amount of time since the weight has been lifted below the elbow position. This activity has a big potential for low back pain (LBP) if it is not treated immediately.

(a)   (b)   (c)   (d)

Image 3. MMH Activities (a Lifting and Carrying Soybean Extraction in Pail; (b) Filtering and Lifting Soybean Extraction; (c) Lifting and Carrying Tofu Barrels; and (d) Tofu Molding and Pressing

Previous research (Asshidiq and As'ad, 2023) carried out measurements utilizing SNI 9011:2021 for the activities of kiosk workers, while (Irhamna and Herbawani, 2021) carried out on cleaning staff and (Susanto *et al*., 2022) for laboratory technicians. Every task has different risks, as doses the object of this research. This measurement aims to provide facts

about complaints or symptoms that could potentially affect MSDs. A contributing element to the development of low back pain is the injury that the spine sustains form excessive loading (Negera, Suadnyana and Listiantari, 2021). Control efforts must be implemented in order to prevent injury from exposure of hazards. Several recommendation control efforts include:

a. Lifting and carrying soybean extraction in pail activity

This activity requires hand force by holding firmly in a power grip position. However, applying pressure directly to the palm has potential for carpal tunnel syndrome. In addition, the lifting load on the pail reaches 35 kg and lifted using right hand. An unbalanced weight is being lifted. The right arm and shoulder are both affected by these activities.

Engineering control recommendation: Designing of tools for soybean extraction handling; providing pad on the pail handle;

Administrative control: Lifting weights instructions for balancing both right and left hands; safety socialization for workers to gain their awareness.

b. Filtering and lifting soybean extraction

The arm movement in this activity is quite rapid while filtering. The substances that is being filtered is heated and includes coagulants. Additionally, carrying tofu extraction has the potential for twisting body. This activity is carried out by one worker with seven days working. Some recommended control effort:

Engineering control recommendation: Designing of automatic or semi-automatic machine to filtering the soybean extraction.

Administrative control: Adding workers (recruitment), setting appropriate working hours and rest hours.

c. Lifting and carrying tofu barrels

To prevent this activity, the recommendation are:

Engineering control recommendation: Designing of tools for tofu barrels handling

Administrative control: Lifting weights instructions; safety socialization for workers.

d. Tofu Molding and Pressing

The body bends because the molding position is too far below the standing elbow, so the recommendations given are as follows:

Engineering control recommendation: Workbench design that is adjusted to the worker

Administrative control: tofu molding instructions; safety socialization for workers

Another different views of modern solutions, research study of (Zelik, Nurse, Schall, Sesek, Marino and Gallagher, 2022) gives the new way to help MMH activities by designing exoskeleton. The exoskeleton is a tool to help workers by decreasing the muscle activity. It can aid in reducing the load on the lumbar spine of workers.

Temperature and illumination in the tofu industry are not conducive to work. Provide air ventilation and additional lighting in order to make workers comfortable and to reduce the potential for work accidents.

CONCLUSION

The conclusion obtained, based on ergonomic assessment, MMH work in producing tofu has a high risk of MSDs. The MSDs symptoms for neck, right shoulder, upper back, arms, lower back, and right hand, with a score of 9. There are high complaints and a high risk of ergonomic factors in MMH activities such as lifting soybean extraction in pail (14), filtering and lifting soybean extraction (19); lifting and carrying tofu barrels (11); and tofu molding and pressing (18).

As a limitation, video data collection considers limited space and moderately high worker mobility activities. For accurate data recording requires adequate storage memory

capacity. The ergonomic risk factor assessment used in this study was based on high complaints of MSDs, while in the future, an assessment of medium complaints also needs to carried out. In order to control recommendations can be provided and implemented to aid in lowering or even preventing the occurrence of the occupational risk of MSD.

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