

MUSCULOSKELETAL DISORDERS RISK ASSESSMENT AMONG SMALL TOFU FACTORY WORKERS IN TANGERANG CITY: AN INDONESIAN CASE STUDY**Kania Viatina¹, Mila Tejamaya^{2*}, Baiduri Widanarko³**¹Department of Occupational Safety and Health, Faculty of Public Health, Universitas Indonesia, Depok, Indonesia²Department of Occupational Safety and Health, Faculty of Public Health, Universitas Indonesia, Depok, Indonesia³Department of Occupational Safety and Health, Faculty of Public Health, Universitas Indonesia, Depok, Indonesia

*Corresponding author: Mila Tejamaya

Email: tejamaya@ui.ac.id; mila.tejamaya@gmail.com**ABSTRACT**

Introduction: Conventional tofu production involves various manual handling tasks which increases the risk of musculoskeletal disorders (MSDs). A previous study found a very high risk of MSDs in tofu manufacturing, especially in the filtering task with a REBA score of 13. **Aims:** This study aims to evaluate the risk of MSDs in tofu factory workers. **Methods:** Workplace observations and unstructured interviews were conducted at two traditional tofu factories (X and Y) and a more modern silken tofu factory to identify the risk of MSDs. The Nordic Musculoskeletal Questionnaire and the Quick Exposure Check (QEC) method were used to determine the prevalence and risk of MSDs. A total of 52 workers voluntarily participated in this study. **Results:** The traditional and silken tofu manufacturing processes involved seven and fifteen tasks, respectively. This study found that workers in the traditional tofu factories had a higher prevalence of MSDs than those in the silken tofu factory. In the past 12 months, traditional tofu factory workers reported MSDs in their lower back (94.4%), right shoulder (77.8%), and neck (61.1%). On the other hand, silken tofu factory workers reported MSDs in their lower back (81.3%), right shoulder (62.5%), and upper back region (56.3%). According to the QEC method, grinding and filtering were identified as two tasks with a very high risk of MSDs in the traditional factories. In addition, transferring tofu crates from cold water to hot water tub in the silken factory was identified as a very high risk of MSDs. **Conclusion:** Intervention is necessary for tasks with a very high risk of MSDs in small tofu factories.

Keywords: ergonomic, MSMEs, musculoskeletal disorders, tofu factory workers, quick exposure check**INTRODUCTION**

Ergonomics is the science of work, the people who do the work, the methods they use, the tools and equipment they use, the workspaces they occupy, and the psychosocial aspects of their working conditions (Pheasant and Haslegrave, 2018). Ergonomics places humans at the center of technological systems (Elbert et al., 2018). Ergonomics is a discipline of science and art and an application of technology to harmonize people with their work environment and equipment by considering human abilities and limitations with the goal of achieving human welfare. Musculoskeletal disorders (MSDs) can

occur as a result of poor ergonomic practices.

MSDs are one of the most common occupational illnesses (da Costa et al., 2015; Widanarko et al., 2014). MSDs include a range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels (Asuquo, Tighe and Bradshaw, 2021). MSDs are a prevalent occupational illness worldwide, causing significant human suffering and economic costs to business and healthcare systems. In the United States, MSDs are responsible for nearly one-third of all occupational injuries and illnesses (Bureau of Labor Statistics, 2016). According to data from the Labour

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Force Survey (LFS) in the United Kingdom, it was found that between 2017 and 2018, 469,000 workers suffered from musculoskeletal disorders, resulting in the loss of 6.6 million workdays.

MSDs are caused by a combination of various factors. Literature reviews and epidemiological studies have identified three groups of risk factors causing work-related musculoskeletal disorders (WMSDs): physical factors (e.g. sustained or awkward posture, repetition of the same movement, forceful exertions, hand-arm vibration, whole-body vibration, mechanical compression, and extreme temperatures); psychosocial factors (e.g., work pace, autonomy, monotony, work/rest cycle, task demands, lack of social support and management, and job uncertainty); and individual factors (e.g., age, sex, professional activities, sport activities, domestic activities, alcohol consumption, and previous WMSDs) (Widanarko et al., 2015).

Production processes carried out in the tofu industry involves a lot of manual handling activities, which can lead to musculoskeletal pains in workers. Risk factors for MSDs in tofu production processes include repetitive movements, manual handling, and awkward postures that have the potential to cause MSDs in workers who perform manual work continuously for a long period of time. This study aims to determine the prevalence of MSDs among tofu factory workers and to perform an ergonomic assessment of their exposure to MSD risk factors.

METHODS

Research Design

This case study was conducted at three small-scale tofu factories in Tangerang City, Indonesia. Two of the factories were traditional tofu factories, while the third was a modern silken tofu factory. This study involved 52 workers, 42 of whom were males and 10 of whom were females, who voluntarily participated. Workers with a history of accidents that

may have affected their musculoskeletal system were excluded from this study. The permission for data collection was obtained from the owner of the tofu factories.

Data Collection

Primary data was collected through observations and interviews. To understand the production process and activities performed by the workers, observations and interview sessions with factory owners, supervisors, and workers were conducted. To investigate the symptoms and prevalence of MSDs, the Nordic Body Map and Questionnaire were used. The level of MSD exposure in the back, shoulder/arm, wrist/hand, and neck regions was assessed using the Quick Exposure Check (QEC) method.

The Nordic Musculoskeletal Questionnaire and QEC Method

The Nordic Musculoskeletal Questionnaire (NMQ) was used to determine the prevalence of MSDs in terms of musculoskeletal symptoms (aches, pains, discomfort) in the past 12 months.

The Quick Exposure Check (QEC) is an observational tool developed to assess the levels of exposure to WMSD risk factors (International Labor Organization, 2021). The QEC method assesses various risk factors, including awkward posture, repetitive movement, maximum weight handled, and task duration. The QEC method quickly assesses the levels of exposure to a combination of MSD risk factors in four body regions (back, neck, wrist/ shoulder, and arm/hand) using a scoring system (Table 1).

Table 1. QEC of Exposure Level

Score	Exposure Level			
	Lo w	Modera te	Hig h	Ver y Hig h
Back (moving)	10- 20	21-30	31- 40	41- 56

	Exposure Level			
Shoulder/arm	10-20	21-30	31-40	41-56
Wrist/hand	10-20	21-30	31-40	41-56
Neck	4-6	8-10	12-14	16-18

To determine the levels of total exposure, the percentage between the actual total exposure score (X) and the maximum feasible total exposure score (X_{max}) was used. For manual handling tasks, X_{max} is 176, while for other tasks, X_{max} is 162 (Oliv *et al.*, 2019). Finally, the QEC method provides four categories for estimating the risk level: a score of 40% or lower indicates low risk (acceptable); a score of 41% to 50% indicates moderate risk, where further investigation is needed; a score of 51% to 70% indicates high risk, where a timely investigation and changes are needed; and a score of higher than 70% indicates very high risk, where investigation and changes are urgently required.

This study has been ethically assessed and approved by the Ethics Committee of the Faculty of Public Health, Universitas Indonesia with a certificate number 320/UN2.F10/PPM.00.02/2019.

RESULTS

Processes and Task Description

The traditional tofu production process involves seven tasks as shown in Figure 1. The tasks included grinding and cooking the soybeans, filtering and coagulating the soy milk, and pressing, cutting, and frying the tofu.

In comparison, the silken tofu production process involves 15 tasks

(Figure 2) that can be grouped into three stages: soymilk preparation, tofu production, and final packing. The preparation process included removing soybean hulls; soaking, washing, grinding and cooking the soybeans; and filtering the soy milk. The filtered soy milk was then processed into three types of tofu products: soft, firm, and egg tofu. The tasks in soft and firm tofu production processes were similar, such as coagulating the filtered soy milk, cutting the tofu, packaging it into retail containers, and vacuum sealing it. Meanwhile, egg tofu production involved mixing the soymilk with egg yolk and adding a coagulant, followed by packing and sealing the egg tofu in a plastic bag. The final process involved heating the tofu in a hot water tub, arranging the products in a crate, and loading the crate of tofu into the cooling room. Figures 3, 4, and 5 shows the postures of the workers.

Characteristics of the Participants

The majority of participants (42, 80.8%) were males and only 10 participants (19.2%) were females. Among the participants, 31 (59.6%) were aged 30 years or younger, while the remaining 21 (40.4%) were older than 30 years. In addition, 35 participants (67.3%) were smokers and only 17 participants (32.7%) were non-smokers. Moreover, 49 participants (76.9%) reported not exercising regularly, while only 12 participants (23.1%) reported exercising regularly. Finally, 28 participants (53.8%) had worked for more than four years, while the other 24 participants (46.2%) had worked for four years or less.

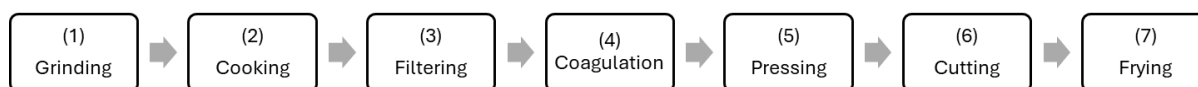
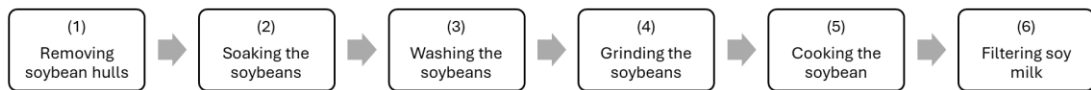
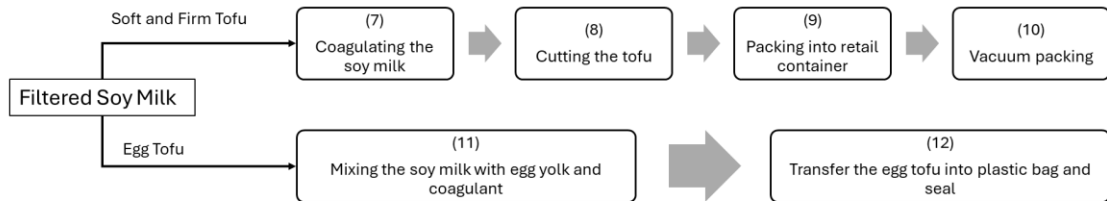


Figure 1. Schematic Diagram of Seven Traditional Tofu Production Process

A. The Soymilk Preparation Process



B. Main Tofu production Process



C. Final Production Process

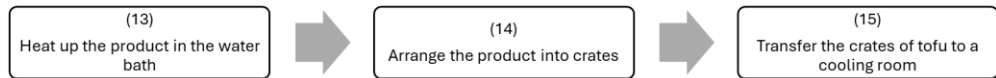


Figure 2. Schematic Diagram of Silken Tofu Production Process



Figure 3. Shoulder/arm posture difference between workers at the traditional tofu factory X (left) and Y (right) while transferring soybeans into a grinding machine



Figure 4. Workers carrying out filtering activities at the traditional tofu factory X (left) and Y (right)



Figure 5. Workers at the silken tofu factory pulling out a crate full of tofu from the cold water tub

Table 2. Prevalence of Musculoskeletal Disorders in the Past 12 Months among Traditional and Silken Tofu Factory Workers in Tangerang City

Body Parts	Musculoskeletal Disorders/Symptoms			
	Traditional tofu factory workers (n = 36)		Silken tofu factory workers (n = 16)	
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)
Neck	22	61%	7	44%
Upper back	19	53%	9	56%
Lower back	34	94%	13	81%
Right shoulder	28	78%	10	63%
Left shoulder	20	56%	8	50%
Right elbow	11	31%	2	13%
Left elbow	4	11%	0	0%
Right wrist	21	58%	7	44%
Left wrist	7	19%	3	19%
Right thigh	17	47%	6	38%
Left thigh	18	50%	5	31%
Right knee	13	36%	4	25%
Left knee	10	28%	4	25%
Right ankle	10	28%	4	25%
Left ankle	6	17%	6	38%

Table 2 presents the prevalence of MSDs in the past 12 months. The results indicated that more than 50% of traditional tofu factory workers reported experiencing musculoskeletal pain in various body regions, including the lower back (94%), right shoulder (78%), neck (61%), right wrist (58%), left shoulder (56%), and upper back (53%). Similarly, in the silken tofu factory, more than 50% of workers reported experiencing musculoskeletal pain in the

lower back (83%), right shoulder (63%), and upper back (56%).

Ergonomic exposure and risks were further assessed using the QEC method. Table 3 presents the results of the ergonomic risk assessment of two traditional tofu factories for seven tasks, while Table 4 presents the results of the ergonomic risk assessment of a silken tofu factory.

Table 3. Ergonomic Risk Assessment Results for Seven Tasks in Two Traditional Tofu Factories X and Y in Tangerang City, Indonesia

Body Parts	QEC Variables	Task																	
		(1) Grinding		(2) Cooking		(3) Filtering				(4) Coagulating		(5) Pressing				(6) Cutting		(7) Frying	
		X	Y	X	Y	Sub Task 1		Sub Task 2		X	Y	Sub Task 1		Sub Task 2		X	Y	X	Y
						X	Y*	X	Y			X	Y	X	Y				
Back	P&W	12	10	10	10	6	-	6	6	4	6	6	6	8	8	4	4	6	4
	P&D	10	10	8	8	10	-	6	6	8	6	10	10	6	6	6	8	8	6
	D&W	12	10	8	8	6	-	10	10	6	6	6	6	8	8	4	6	4	4
	F&W	8	6	6	6	6	-	6	6	2	4	4	4	6	6	2	2	2	4
	F&D	6	6	4	4	10	-	6	6	6	4	8	8	4	4	4	6	4	6
	Score	48	42	36	36	38	0	34	34	26	26	34	32	32	20	26	24	24	4
Exposure	VH	VH	H	H	H		H	H	M	M	H	H	H	H	L	M	M	M	
Shoulder/Arm	P&W	12	8	6	6	4	-	6	6	2	4	2	4	8	8	2	2	2	2
	P&D	10	8	4	4	8	-	6	6	6	4	6	8	6	6	4	6	4	4
	D&W	12	10	8	8	6	-	10	10	6	6	6	6	8	8	4	6	4	4

Body Parts	QEC Variables	Task																	
		(1) Grinding		(2) Cooking		(3) Filtering				(4) Coagulating		(5) Pressing				(6) Cutting		(7) Frying	
		X	Y	X	Y	Sub Task 1		Sub Task 2		X	Y	Sub Task 1		Sub Task 2		X	Y	X	Y
						X	Y*	X	Y			X	Y	X	Y				
F&W	F&W	8	6	6	6	6	-	8	8	4	6	6	6	8	8	6	6	2	6
	F&D	6	6	4	4	10	-	8	8	8	6	10	10	6	6	8	10	4	8
	Score	48	38	28	28	34		38	38	26	26	30	34	36	36	24	30	16	24
	Exposure	VH	H	M	M	H		H	H	M	M	M	H	H	H	M	M	L	M
Wrist/Hand	F&K	6	6	6	6	8	-	8	8	6	10	4	6	6	6	8	8	8	4
	F&D	6	6	4	4	8	-	8	8	8	8	6	6	4	4	8	10	6	6
	D&K	10	10	8	8	10	-	10	10	8	8	8	10	8	8	6	8	8	4
	P&K	8	8	8	8	8	-	8	8	6	8	6	8	8	8	6	6	8	4
	P&D	8	8	6	6	8	-	8	8	8	6	8	8	6	6	6	8	6	6
	Score	38	38	32	32	42		42	42	36	40	32	38	32	32	34	40	46	24
	Exposure	H	H	H	H	VH		VH	VH	H	H	H	H	H	H	H	H	H	VH
Neck	P&D	8	8	6	6	8	-	8	8	8	6	8	8	6	6	8	8	6	6
	V&D	6	6	4	4	6	-	6	6	8	6	6	6	4	4	6	6	4	4
	Score	14	14	10	10	14	-	14	14	16	12	14	14	10	10	14	14	10	10
	Exposure	H	H	M	M	H		H	H	VH	H	H	H	M	M	H	H	M	M

Body Parts	QEC Variables	Task																	
		(1) Grinding		(2) Cooking		(3) Filtering				(4) Coagulating		(5) Pressing				(6) Cutting		(7) Frying	
		X	Y	X	Y	Sub Task 1		Sub Task 2		X	Y	Sub Task 1		Sub Task 2		X	Y	X	Y
						X	Y*	X	Y			X	Y	X	Y				
Total Score	148	132	106	106	128	128	104	104	10	10	110	120	110	110	91	110	96	82	
Percentage (%)**	84	75	60	60	73	73	73	73	59	59	63	68	63	63	52	63	55	47	
Ergonomic Risk Level	VH	VH	H	H	VH	VH	VH	VH	H	H	H	H	H	H	H	H	H	H	M

Note:

P: posture; W: weight; D: duration; S: static posture; F: frequency; K: force; V: visual demand

*In Y factory, a transfer machine was used to replace manual transfer

**Percentage = (total score/176) x 100%

Table 4. Ergonomic Risk Assessment Results for 15 Tasks in a Silken Tofu Factory in Tangerang, Indonesia

Body Parts	QEC Variables	Soft and Firm Tofu												Egg Tofu		13	14	15
		1	2	3	4	5	6	7	8	9	10	11	12					
		P&W	6	12	6	6	4	2	8	8	2	6	8	2	12			
P&D	10	6	10	8	6	4	8	8	4	8	8	6	8	4	6			
D&W	6	8	6	4	4	4	6	6	4	4	6	6	10	4	6			
S&D	-	-	-	-	-	4	-	-	4	-	-	8	-	4	-			
F&W	4	8	4	4	2	-	6	6	-	4	4	-	12	-	6			
F&D	8	2	8	6	4	-	6	6	-	6	4	-	8	-	2			
Score	34	36	34	28	20	14	36	34	14	28	30	22	50	14	30			
Exposure	H	H	H	M	L	L	H	H	L	M	M	M	VH	L	M			

Body Parts	QEC Variables	Soft and Firm Tofu												13	14	15
		1	2	3	4	5	6	7	8	9	10	11	12			
Shoulder/Arm	P&W	6	8	2	6	2	2	8	6	4	2	4	2	8	4	10
	P&D	10	2	6	8	4	4	8	6	6	4	4	6	4	6	6
	D&W	6	8	6	4	4	4	6	6	4	4	6	6	10	4	6
	F&W	4	8	4	4	2	2	6	6	6	6	4	6	10	6	6
	F&D	8	2	8	6	4	4	6	6	8	8	4	10	6	8	2
	Score	34	28	26	28	16	16	34	30	28	24	22	30	38	28	30
	Exposure	H	M	M	M	L	L	H	M	M	M	M	M	H	M	M
Wrist/Hand	F&K	4	6	8	6	4	4	6	6	4	4	6	6	6	6	6
	F&D	6	2	8	4	4	6	4	4	6	6	4	10	4	6	2
	D&K	8	6	10	8	6	4	8	8	4	4	8	6	8	6	6
	P&K	6	8	8	8	6	4	8	8	4	4	8	4	8	6	8
	P&D	8	4	8	6	6	6	6	6	6	6	8	8	6	6	4
	Score	32	26	42	32	26	24	32	32	24	24	34	34	32	30	26
	Exposure	H	M	VH	H	M	M	H	H	M	M	H	H	H	M	M
Neck	P&D	8	4	8	6	6	6	6	6	6	6	6	8	6	6	4
	V&D	6	2	6	4	4	4	4	4	6	4	4	6	4	4	2
	Score	14	6	14	10	10	10	10	10	12	10	10	14	10	10	6
	Exposure	H	L	H	M	M	M	M	M	H	M	M	H	M	M	L
Total Score		114	96	116	98	72	64	112	106	78	86	96	100	130	82	92
Percentage (%)**		65	55	66	56	41	36	64	60	44	49	55	57	74	47	52

Body Parts	QEC Variables							Soft and Firm Tofu				Egg Tofu		13	1 4	1 5
		1	2	3	4	5	6	7	8	9	10	11	12			
		Ergonomic Risk Level	H	H	H	H	M	M	H	H	M	M	H			

Note:

P: posture; W: weight; D: duration; S: static posture; F: frequency; K: force; V: visual demand

**Percentage = (total score/176) x 100%

Table 5. Number and percentage of tasks with various ergonomic risk levels

Ergonomic Risk Level	Number of Tasks							
	Low		Moderate		High		Very High	
	n	%	n	%	n	%	n	%
Factory								
Traditional Tofu Factory X	0	0	0	0	6	67	3	33
Traditional Tofu Factory Y	1	11	1	11	5	56	2	22
Silken Tofu Factory	0	0	5	33	9	60	1	7

According to the QEC results, the risk of developing MSDs for the silken tofu factory workers was relatively lower than that for the traditional tofu factory workers (Table 5). In addition, the risk of MSDs at traditional factory X was higher than that at factory Y since factory Y replaced the manual transfer of soybean slurry with a pump.

DISCUSSION

In line with other similar studies, the tofu manufacturing industry relies heavily on manual handling, which is associated with a higher risk of developing MSDs (Moradi and Barakt, 2020; Widodo et al., 2021; Erliana et al., 2023). This study found that the 12-month prevalence of MSDs among tofu factory workers was quite significant, where more than 50% of participants from traditional and silken tofu factories reported experiencing musculoskeletal pain in six body regions (lower back, right shoulder, neck, right wrist, left shoulder, and upper back) and three body regions (lower back, right shoulder, and upper back), respectively. Rahayuningsih et al. (2018) showed that the

waist, right shoulder, and upper right shoulder were the three main body regions that were most frequently affected by MSDs as reported by tofu factory workers in Kediri, Indonesia. Similarly, in this study, the prevalence of MSDs in the right shoulder was greater than 50% for both traditional and modern tofu factory workers.

The levels of exposure to MSD risk factors in the back, shoulder/arm, hand/wrist and neck were assessed by the QEC method. In general, higher levels of exposure to ergonomic risk factors were found among traditional tofu factory workers compared to modern silken tofu factory workers (Table 5). For example, grinding and filtering are two tasks with a very high risk of MSDs in the traditional tofu factories, while in the silken tofu factory, the risk of MSDs was categorized as high and medium risk.

In fact, workers at traditional factory X and Y had significant differences in exposure levels. For instance, the levels of exposure to the shoulder/arm of workers who performed grinding activities at traditional tofu factory X were higher compared to those at factory Y due to poor

posture combined with heavier load weight. The hoppers of the grinding machines at traditional tofu factory X were positioned higher than those at factory Y. The hoppers at factory X exceeded the normal reach of the workers, requiring them to fully extend their arms while simultaneously placing soybeans into the grinding machine. In addition, the maximum weight being handled by workers while performing grinding activities at factory X (>20 kg) was greater than at factory Y (>15 kg). Co-exposure between exertion and carrying 20% to 40% of body weight load can affect trunk posture and lead to musculoskeletal injuries (Simpson et al., 2011). Exposure to more than one ergonomic hazard was found to be significantly associated with the likelihood of MSDs (Park and Kim, 2020).

The filtering task performed by the two factories also differed. Factory X divided the task into two sub-tasks: transferring the soybean slurry into the cheese cloth and filtering the soybean slurry to extract soymilk. On the other hand, factory Y substituted the first sub-task by using a pumping machine. Despite these differences, workers at both factories were still exposed to very high levels of risk, particularly in the wrist/hand due to the highly repetitive movements in the filtering activities. In addition, the task required workers to handle weights of up to 15 kg with their hands/wrists while bending and moving between 11 to 20 times per minute (Figure 4). This finding is consistent with the study conducted by Eriana et al. (2023) in North Aceh which identified a very high ergonomic risk of MSDs associated with filtering activities.

Both grinding and filtering tasks at the two traditional factories were categorized as very high risk of MSDs, thus requiring urgent investigation and changes. Other tasks posed moderate to high risk, thus necessitating timely investigation and changes are required.

Siska and Harahap (2022) proposed an engineering control intervention by creating an ergonomic soaking station in

order to eliminate body exertion during soybean transfer in the grinding process. This approach reduced the risk of MSDs from a very high level to an acceptable level.

In the observed silken tofu factory, only one task, which was the tofu heating task, showed a very high risk of MSDs with a score of 74%. This was due to the manual activity of transferring the tofu crate from the cold water to hot water tub. The backs of the workers were excessively flexed with more than 60° of flexion while moving the tofu crates (Figure 5). In addition, the weight being handled by the workers during this task was very heavy, up to 20 kg. Co-exposure of awkward posture and heavy loads at the silken tofu factory posed a very high risk of MSDs. Therefore, urgent investigation and changes are required (Park and Kim, 2020).

CONCLUSION

The results showed that the prevalence of MSDs among tofu factory workers were high. More than 50% of workers in both traditional and modern tofu factories reported experiencing musculoskeletal pain in the past 12 months. Based on the QEC assessment results, workers in the traditional tofu factory were exposed to a higher risk of MSDs compared to those in the more modern silken factory due to the replacement of some manual handling tasks with machinery. To reduce the risk of MSDs to workers, an engineering intervention is necessary for grinding and transferring soybean slurry at traditional tofu factories and moving crates from cold water into hot water tub.

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