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Mohd Hasnun Arif Hassan
Mohd Nadzeri Omar
Nasrul Hadi Johari
Yongmin Zhong *Editors*

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Preface

Technological advancements have significantly benefited humans. Technology has led to the development of ergonomic tools and equipment that improve human comfort, reduce strain, and enhance overall productivity. From adjustable office chairs to ergonomic keyboards, these innovations promote proper posture and reduce the risk of musculoskeletal disorders. When it comes to road safety, technology has played a pivotal role in saving lives and preventing accidents. Advanced driver assistance systems (ADAS) equipped with sensors, cameras, and artificial intelligence algorithms help detect potential hazards, warn drivers, and even intervene if necessary. In the realm of sports technology, advancements have revolutionized training methodologies and performance analysis. Athletes now have access to wearable devices that monitor their biometric data, providing insights into their physical condition, performance metrics, and injury prevention. Further, technological advancements have led to sophisticated tools and methods for studying the human body's mechanics and movement. High-speed cameras, force sensors, and motion-tracking systems enable researchers to gain deeper insights into human locomotion, joint mechanics, and muscle activation patterns. These findings help design better prosthetics, rehabilitation programs, and ergonomic solutions tailored to individual needs.

The "Unlocking Human Potential: The Future of Human Engineering" symposium seeks to delve into the cutting-edge field of human engineering, exploring the possibilities of augmenting and optimizing human capabilities through advancements in science, technology, and design. This symposium brings together experts from various disciplines to discuss and showcase innovative approaches, methodologies, and ethical considerations in the realm of human engineering. From neuroenhancement to prosthetics, cognitive augmentation to genetic engineering, this symposium aims to stimulate insightful discussions and inspire the creation of a future where human potential knows no bounds.

Pekan, Malaysia — Mohd Hasnun Arif Hassan

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About the Editors

Dr. Mohd Hasnun Arif Hassan earned his first degree in Mechanical Engineering from the Technische Hochschule Bingen, Germany, in 2010. During the final year of his undergraduate study, he was offered a scholarship by Universiti Malaysia Pahang (UMP) to pursue a Master's degree in Mechanical Engineering at the University of Malaya in Kuala Lumpur, which he graduated with distinction in 2012. After that, he embarked on his Ph.D. journey at UMP where he studied about the head injury sustained by soccer players due to heading manoeuvre. He completed his Ph.D. study in 2016 and then continued to serve UMP as a senior lecturer. His research interests include finite element modelling of the interaction between human and sports equipment, instrumentation of sports equipment, and injury prevention particularly with regards to sports and traffic accidents. His work aims to apply engineering principles in sports not only to enhance the performance of an athlete but also to prevent injuries.

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Dr. Nasrul Hadi Johari obtained his Ph.D. in Biofluid Mechanics from Imperial College London, United Kingdom. He is currently a senior lecturer at the Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang. Dr. Johari's research activities include computational modeling of blood flow, tissue mechanics, and mass transport in the cardiovascular system, with applications ranging from evaluating the hemodynamic performance of medical devices to predict the outcome of endovascular interventional procedures. He is also interested in computational and experimental modeling of the interaction between human

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Risk Assessment for Manual Handling Activities in a Dairy Industry

Khairulhafiy Muhammad Ruzairi, Ezrin Hani Sukadarin, Mirta Widia, and A. Alaman

Abstract Workers in the dairy industry work in integrated plant facilities such as process hall, maintenance and utility, warehouse logistics, and quality checking. All workers are at risk for work-related injuries and job-related illnesses. This study aims to assess the ergonomic risk factor in manual handling activities in the dairy plant industry. Field observation and manual handling assessment charts (MAC) tool determined the ergonomic risk factor. The process hall department is the main sector where there are various areas from process raw receiving, raw storage, batching operations, and pasteurised storage to filling and packaging operations. The result found several hazards of manual activities, such as awkward posture, forceful exertion, repetitive motion, static posture, and contact stress. The highest score of ergonomic risk factor was found at the filling workstation during carrying weight load activities. Thus, controlling exposure to occupational hazards is the fundamental method of protecting workers.

Keywords Manual handling activities · Risk assessment · Dairy industry

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1 Introduction

Malaysia is one of the most important importers of milk besides Russia and China [1]. Based on the Malaysia Trade Statistics report, the high import dependence rate (IDR) according to selected food products for livestock are mutton (88.8%), beef (76.4%), and fresh milk (41.9%) [2]. Despite the rapid expansion of the dairy industry, there are many challenges, such as a lack of skills and training, inefficient employee performance, and a poor working environment [3]. The environmental impact of socio-employment issues in this field has not been addressed well [4]. For example, studies on dairy industry development and dairy farming industry involving dairy operation milking systems [5], such as stanchion and parlour systems operation [6] or related intervention on exposure risks to musculoskeletal symptoms among milkers in dairy farming [7] seem broad. Unfortunately, studies highlighting ergonomics or safety and health among dairy plant manufacturing workers managing downstream production regarding labelling requirements, food additives, and packaging still need to be widely published. The company must focus on ergonomics implementation to remove barriers to quality, productivity, and safe human performance by fitting products, tasks, and environments instead of forcing the person to adapt to the work [8]. According to existing ergonomic manufacturing and dairy studies, musculoskeletal disorder (MSD) from manual activities is a disease that workers often experience in factory plants due to physical and psychosocial factors and combining risk factors at once [6, 9–13].

This study was conducted at a dairy factory that manufactures dairy products in Subang, Selangor. There are very lacking studies on ergonomic risk assessment at dairy plant factories in Malaysia. Thus, the objective of this study is to conduct an ergonomic study to fill the existing knowledge gap. In addition, researchers also believe that this would help effective productivity by enhancing the oversight of adopting ergonomic aspects within the context of dairy factory work.

2 Methodology

The research design that has been used for this study is a case study. The type of data collection is quantitative data. In the early research stage, workplace screening identifies ergonomics concerns by conducting field observation [6, 9].

2.1 Field Observation

Field observation has been done in four departments: (1) the process hall, (2) the maintenance hall, (3) the warehouse and logistic house, and (4) the quality checking department. Thus, only the process hall is included in this study (Fig. 1), considering

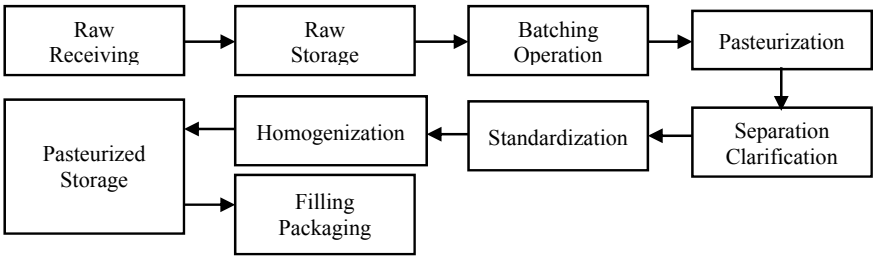

Fig. 1 Production process flow at the process hall

the worst-case scenario based on the duration of exposure and severity of consequences. The time limitation has been a barrier to considering all departments. The task description at the process hall is presented in Table 1 to understand the selected process better.

2.2 Manual Handling Hazards Identification at the Workstations

The process hall is divided into 7 workstation areas–blow moulding area, tipping, yoghurt filling room command line (CMD), packaging area CMD, yoghurt packing area, assorted room, and kitchen (clean in place (CIP)). The clarification of each of what applies at the workstation in the process hall can be seen in Table 2.

2.3 The Manual Activities Assessment Chart (MAC Tool)

The Manual Activities Assessment Chart (MAC tool) was used to assess the risks posed by manual handling activities at the stage of Malaysian Advanced Ergonomic Risk Assessment (Advance ERA) (DOSH 2017). Table 3 shows the colour-coding score system in MAC.

There is a score sheet to complete at the end of the tool. The purpose of the MAC assessment is to identify and reduce the overall risk level of the task. Three types of assessment can be carried out with the MAC: lifting operations, carrying operations, and team handling operations. Figure 2 shows an appropriate assessment guide and flowchart to conduct Advance MAC [19].

Table 1 Task description of each process at the pocess hall

Process	Task Description
Raw receiving	The quality team upon receipt of raw milk from the tank truck will perform standard testing involving odour, temperature, and laboratory testing
Raw storage	Raw milk is stored in a vertical silo tank in an untreated condition, so the team will monitor two variables, i.e. the temperature and time the raw milk is stored that should be given attention
Batching operation	Satisfying the recipe and producing a sufficient batch quantity depends on the batching process, which is a fast process of combining liquid and dry ingredients in the prescribed dosage
Pasteurisation	The pathogen will be destroyed using high-temperature short time (HTST)
Separation clarification	Separating skim milk from cream uses centrifugal forces to separate the cream from the skim so that it can be used in other products
Standardisation	Standardisation is the process of adjusting the fat content of milk to a specified value so that the taste and content are uniform when it reaches the consumer. This process includes blending cream and skim via monitoring the ingredient and product characteristics. After separation, combine calculated volumes of cream and skim into batch tanks under continuous agitation. Operators confirm product characteristics via lab testing and adjust as required
Homogenisation	The homogeniser forces hot milk at high pressure through a narrow slit, breaking up lumps of fat so that the tid-ak can recombine later to prevent the formation of a thick layer of cream on the surface
Pasteurised storage	Although pasteurisation kills disease-causing bacteria and prolongs shelf life, even pasteurised milk can quickly spoil and cause foodborne illness if not handled properly. Refrigeration is critical in ensuring milk safety: the hotter the milk, the faster the bacteria grow and multiply. Typical storage temperatures are 36° F to 38° F (2 °C to 3 °C)
Filling packaging	Workers will sit or stand to remove bottles or boxes with defects in this process Filling–In the processing line, milk will be transferred in various types of packaging in bottles, boxes, or cartons Packaging–organise product containers into easily stored and transported cartons, boxes, and palettes

3 Results

3.1 Manual Handling Hazard Identification

Based on the field observation, it was found that manual handling activities are common. It was revealed that workers are exposed to the risk factors such as lifting, bending, forward-reaching, twisting, improper tools, crowded spaces, and slippery floors, which can develop occupational illness. However, there were no serious injuries as a result of negligence or as a result of not adhering to good practice of manual handling. Yet there are minor injuries such as numbness due to sitting

Table 2 Task description of each workstation area at the process hall

Workstation	Task description
Blow moulding area	This activity involved prolonged sitting and repetitive sideway body twisting. The object handled is weight 25 kg, bulky, and slippery. The repetitive activity is done for 2 h duration. Working duration is 12 h with one hour of rest and rotation or work every 2 h: crowded space and slippery floor. Warm temperature
Tipping	This activity involves a standing position. The object handled weighs 15.5 to 50 kg, which is bulky and slippery. Working hours depend on the schedule but mostly do not exceed one hour, and the working temperature is slightly warm
Filling room (CMD/ yoghurt)	This activity of generating the machine was done in a standing position. The hip sheet transferred is weighed 75 kg, bulky, and had a sharp end. The packaging foil being changed weighed 10.7 kg and involved movement above the shoulder. Minimum twisting, pulling, and forward reaching
Packaging area	Observe the bottles coming out from the filling room, unwrap the rejected packaging, and put the bottles from the conveyor belt into the box
Yoghurt packing area	This activity involved standing position for a long time, and it has maximum sideways twisting and bending down. The handling of the object performed more than once was carried out every minute for more than one hour. The work duration is 12 h with one hour break
Assorted room	This activity was done in standing and some in sitting positions. Significant movement of bending, repetitive sideways twisting, forward-reaching, pulling, and pushing. No reaching above shoulders. The handling of the object performed more than once was carried out every 3 min approximately and more than one hour. Working hours are 12 h with rotation from contract workers at the yoghurt packaging line once with one hour rest. The chair provided is not in good condition and has a sharp edge
CIP kitchen	Required to lift the drum weighed 25 kg to other production areas. It involves a narrow area which sometimes can be slippery. Involved bending to the side to lift up the chemical tank

Table 3 The colour-coding score system in MAC

Color Coding	Level of Risk	Description
G - Green	Low level	Contemplate risky group (pregnancy, disabled, inexperience workers)
A - Amber	Medium level	Examine tasks closely.
R – Red	High level	Immediate action is needed. Might expose a significant part of the working population to risk of injury.
P - Purple	Unac-ceptable level	Situation which places individual's life or health in immediate jeopardy the department shall take into account the provider's professional standards

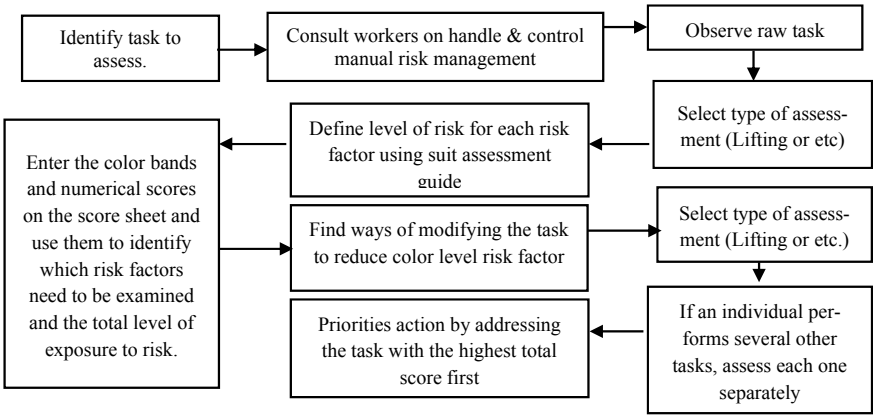

Fig. 2 Flowchart to conduct MAC assessment adopted from HSE UK [14]

and standing for too long. Although slippery is not included in the type of manual handling hazard, lifting heavy loads repeatedly in an uneven train has resulted in injuries because workers do not have a free hand to hold a handrail or put out to break their fall.

The outcome of manual handling hazard identification at the dairy industry is separated into seven workstations: blow molding area, tipping, filling room, packaging area, yogurt packing area, assorted room, and CIP Kitchen. All the activities are the potential to harm workers, such as muscle and joint damage, fractures and soft-tissue injuries, back pain, muscle cramp, and compression on the spinal discs. The potential risk was obtained after hazard identification had been carried out, as presented in Table 4.

3.2 Manual Handling Risk Assessment (MAC Score Sheet)

Table 5 shows the risk assessment of the discussed hazards in the dairy industry. The result indicates that load weight and lift/carry frequency is the risk factor that gives the highest score during lifting and carrying at blow moulding, tipping, and filling room area. Meanwhile, trunk twisting/sideways bending and asymmetrical trunk/load (carrying) are the highest risk factors for packaging, yoghurt packaging, and assorted room area.

Table 4 Potential significant hazards

Workstation	Task	Hazard	Narrative risks
Blow moulding area	Lift 25 kg bag of resin from warehouse to mixer, climb platform, carry the bag to the resin storage tank for machines 1 and 2 and assort the bottles. Warm temperature	Heavy lifting	Expose to unassisted frequent or forceful manual lifting without lifting devices
		Heavy carrying	Expose to the amount of physical effort required to perform a task (such as carrying) or to maintain control of equipment or tools without devices
		Prolonged handle sitting position	Expose to the performance of a task from one postural position for an extended duration. When the combination of force, posture, and time. The cause of the degree of risk is in proportion to the variety of the magnitude of the external resistance, awkwardness of the posture, and duration
Tipping	Lifting the bulky and slippery ingredient bag from the conveyor, shaking the ingredient bag, and pouring the ingredient into the tipping powder machine. Warm temperature	Heavy lifting	Expose as impingement or injury by hard, blunt objects, equipment or instruments when grasping, balancing, or manipulating during tipping task
		Heavy carrying	Expose as the average number of movements or exertions performed by a joint or a body link within a unit of time or performing similar motions with the same body part. The stabilising or antagonistic tendon and muscle groups are used to tipping position and stabilise the extremity in space
		Prolonged handle standing position	Expose to the performance of a task from one postural position for an extended duration
Filling room (C.M.D./ yogurt)	Generating the machine, stand the bottles, changed the hip sheet and the yoghurt packaging seal	Prolonged handle standing position	Expose to the performance of a task from one postural position for an extended duration
		Pushing and pulling	Workers were observed repetitively pulling and pushing with minimum force

(continued)

Table 4 (continued)

Workstation	Task	Hazard	Narrative risks
Packaging area	Observe the bottles coming out from the filling room, unwrap the rejected packaging, put the bottles from the conveyor belt into the box	Prolonged handle standing position	Expose to the performance of a task from one postural position for an extended duration
		Heavy lifting	Even if loads are light, holding items increases the risk of back and shoulder injury since muscles can be starved of nutrients and waste products can build up. Repeatedly exerting, such as lifting bottles, can fatigue muscles by limiting recuperation times
		Pushing	Pushing and pulling activity at a minimum level should be examined because this practice's frequency can also cause strain on the shoulder and hand
Yoghurt packing area	Taping the packaging material, open the box, put the yoghurt into the box, then on the conveyor belt to be sealed, and put the box on the pallet	Prolong handle Sitting position	Prolonged exposure without lumbar support and the rate of muscle discomfort level increased over time among workers
Assorted room	Supply tray, Supply product, arrange product on the conveyor, supply straw to the product, check to reject the product, bundle wrapper and check bundle	Pulling and pushing	Workers were observed repetitively pulling and pushing with minimum force but in long-duration with unsuitable chairs while sitting
		Heavy carrying	Expose as the average number of movements or exertions performed by a joint or a body link within a unit of time or performing similar motions with the same body part within a long duration period
CIP kitchen	Lifting the caustic soda drum	Heavy lifting	Holding and lifting bulky and oversized items in an uneasy way

4 Discussion

Based on the observation, it was found that manual handling activities are very common in dairy plant industry. It was revealed that workers are exposed to the risk factors such as lifting, bending, forward-reaching, twisting, using improper tools, crowded spaces, and slippery floors, which can develop an occupational illness. However, there were no serious injuries as a result of negligence or as a result of not adhering to good practice of manual handling.

Table 5 The result of MAC for six workstations

RISK FACTORS	Blow Moulding Area				Tipping				Filling Room			
	Colour		Score		Colour		Score		Colour		Score	
	Lift	Carry	Lift	Carry	Lift	Carry	Lift	Carry	Lift	Carry	Lift	Carry
Load weight & lift/carry frequency			4				4	4			10	10
Hand distance from the lower back				3			3	0			0	0
Vertical lift region			0				3				0	
Trunk twisting/sideways bending. Asymmetrical trunk/load (carrying)			0				1	1			0	0
Postural constraints			1	1			3	3			1	1
Grip on the load			2	2			2	3			2	2
Floor surface			2	2			0	0			0	0
Other environment factors			1	1			1	1			0	0
Carry distance				0				0				0

RISK FACTORS	Packaging Area				Yoghurt Packaging Area				Assorted Room			
	Colour		Score		Colour		Score		Colour		Score	
	Lift	Carry	Lift	Carry	Lift	Carry	Lift	Carry	Lift	Carry	Lift	Carry
Load weight & lift/carry frequency			0	0			0	0			0	0
Hand distance from the lower back			0	0			0	0			0	0
Vertical lift region			0								0	0
Trunk twisting/sideways bending. Asymmetrical trunk/load (carrying)			1	1			2	2			2	2
Postural constraints			0	0			1	1			1	1
Grip on the load			0	0			0	0			0	0
Floor surface			0	0			0	0			0	0
Other environment factors			0	0			0	0			1	1
Carry distance				0				0				0
Obstacles en route (carying only)				0			0	0				0

The results from MAC can assert that, unknowingly, workers there are prone to MSD, such as muscle and joint pain, tendonitis, swelling and numbness and lower low back pain (LBP). This is due to frequent lifting and carrying of weights, frequent

and vigorous manual lifting without unsafe assistance without team members, repetitive movements, support equipment, and traction forces that do not meet standard procedures.

This compliance can be done by focusing on red codes and considering a number of potential control measures that can be implemented to employees, particularly the use of mechanical supports and work shifts. Management is responsible for providing awareness by implementing administrative control strategies and investing costs in engineering controls to ensure safety by eliminating the hazard or minimising its level of risk by adding control measures, if necessary.

After implementing the MAC score sheet in this study, it can calculate and prioritise ergonomic risks that the highest risk according to the sequence, then propose control measures for intervention. Referring to Table 6, we place according to the ranking based on the worst to the lowest score sheet and also suggest the control measures based on the risk of the task being assessed.

Table 6 Proposed control measures

Workstation area–total score	Proposed control measures
Tipping (Lifting: 17)	Implement buddy system to lift the bulky thing [15] Provide cotton glove [16] Utilise mechanical carrying aids or equipment [17]
Filling room (Lifting: 13)	Provide cotton gloves [16] Utilise mechanical carrying aids or equipment [17]
Filling room (Carrying: 13)	
CIP kitchen (Lifting: 13)	Reorganise the activity or environment to further reduce the impact on the individual(s) [18] Wearing rubber boots prior to entering the area [19]
Tipping (Carrying 12)	Manual handling training [19] Utilise mechanical carrying aids or equipment [17]
CIP kitchen (Carrying: 11)	Reorganise the activity or environment to further reduce the impact on the individual(s) [18] Wearing rubber boots prior to entering the area [18]
Blow moulding area (Lifting: 10)	Refresh manual handling training [19] Implemented job rotation [20]
Blow moulding area (Carrying: 10)	
Assorted room (Lifting:4)	Provide cotton gloves[16] Utilise mechanical carrying aids or equipment [17]
Assorted room (Carrying:4)	
Assorted room (Lifting:4)	Provide cotton gloves [16] Implement buddy system to lift the bulky thing [15]
Yoghurt packaging area (Lifting:3)	
Yoghurt packaging area (Carrying:3)	
Packaging area (Lifting: 1)	Administrative control (make a period of fatigue recovery and job rotation) to reduce the duration, frequency and severity of exposure to risk factors [15]
Packaging area (Carrying: 1)	

5 Conclusion

The result found several hazards of manual activities, such as awkward posture, forceful exertion, repetitive motion, static posture, and contact stress. The highest score of ergonomic risk factor was found at the filling work-station during carrying weight load activities. Implementing a buddy system to lift bulky things is the most suitable control measure in most of the workstation risk factors reviewed.

The limitation of this study is the lack of combining risk factor study material and lacking study that can determine the association between the manual handling risk factor and psychosocial in the formation of MSD. Consistent measurement and concept of the survey in combining risk factors should be clear and researched further. That is a high potential for combining risk factors in future research studies.

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