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Initial Ergonomic Assessment for Handling Concrete Blocks from Curing Pond to Testing Machine

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Abstract: Handling concrete blocks from the curing pond to the testing machine was the subject of the initial Ergonomic Risk Assessment (ERA) conducted at the concrete laboratory of the School of Civil Engineering at UIT Shah Alam. In order to complete the assessment, a five-lab technician is doing the research work for the lecturer and students. Assessing workstation ergonomics, identifying problematic postures using Ergonomic Risk Factors (ERF), and improving worker comfort, safety, and health were the main goals. As per the 2017 Ergonomics Risk Assessment at the Workplace recommendations, the survey revealed that employees experienced severe pain and discomfort, particularly in the lower back, knee, upper arm, and shoulder. Four out of five technicians complained of shoulder pain, one reported pain in the upper arm, two reported knee pain, and pain in the upper and lower back was also reported. The results emphasized the dangers of awkward, repetitive postures and inappropriate load management. In order to address these concerns and provide a more comprehensive assessment and improvement of working conditions, it is recommended that additional evaluations be conducted using the Rapid Whole-Body Assessment (REBA) and the Manual Handling Assessment Chart (MAC). Additionally, the investigation suggests that administrative and engineering controls should be implemented to mitigate the risk of musculoskeletal disorders (MSDs) and enhance the overall ergonomic experience of employees.

Keywords: *Ergonomic Risk Assessment (ERA), Musculoskeletal Disorders (MSD), Awkward Posture, Cornell Musculoskeletal Discomfort Questionnaire, Concrete Laboratory*

1.0 INTRODUCTION

A concrete laboratory is a place where lecturers and students conduct their research for concrete-related studies. This study was conducted in the School of Engineering, UiTM Shah Alam, according to a complaint lodged by a technician who handles this task due to the possibility that ERF exposure could raise the risk of an accident at work. Because all workers, regardless of their profession, may be exposed to risk factors at work, this study aims to reduce workplace risk, particularly with regard to ergonomic risk. According to Baruah (2023), the workers adopted sitting and bending positions when completing the brick-making task. Workers in the current study were observed adopting a variety of postures while carrying out various tasks, which were evaluated using the observation method and still photography methodology. Since the lab technician must perform physical tasks as part of their daily routine, it may cause Musculoskeletal disease (MSD). MSDs are the primary cause of absenteeism from work, one of the primary reasons for lost work time, higher labour expenses, and worker injuries (A Choobineh et al, 2013). The selected target work activities centre around removing the concrete cube from the curing pond, transporting it to a testing machine, and testing the sample. This task involved heavy lifting, repetitive movement, and awkward positions. Heavy physical labour, excessive and repetitive motion, reinforcing tasks requiring challenging postures, and other activities are linked to MSDs (Choi et al., 2014).

Students and researchers design, mix, and test concrete mixes in this laboratory. One of the experiments conducted here is the compressive strength of the concrete cube. Curing the concrete cube in the curing pond is one of the steps in the process. The specimen must be moved from the curing pond to the testing equipment by a lab worker after either seven or 28 days of curing. The work process is handled manually, where lab technicians need to pick up the sample from the curing pond and carry it to the testing machine. The pond is lower than knee height, and they need to bend to pick the samples repetitively. The normal cube size for testing the compressive strength of concrete is 150 mm x 150 mm x 150 mm, which is approximately 8.1 kg, in accordance with British Standards, especially BS 1881-108:1983 (Testing concrete – Method for creating test cubes from fresh concrete). The area between the testing machine and the curing pond is too small for a wheelbarrow, so they must carry it by hand.

This task is subjected to a variety of ergonomic dangers, and these risks might have an impact on the development of musculoskeletal disorders, an occupational disease. For the tasks performed by the lab technician, it is necessary to assess that considered as a problem or trouble since these ergonomic risk factors (ERFs) may have an impact on how well they perform at work when handling samples in the lab. Finding the ERFs that might provide a risk of harm to lab workers and conducting an ergonomic risk assessment in compliance with Department of Safety and Health (DOSH) guidelines were the objectives of this study.

2.0 LITERATURE REVIEWS

MSDs are conditions or injuries that impact the tendons, ligaments, joints, muscles, bones, and nerves. They typically appear gradually as a result of bad posture, overexertion, or repetitive motions. Back discomfort, shoulder and neck pain, carpal tunnel syndrome, tendinitis, and muscle strain are examples of common MSDs. According to Kuok Ho Daniel Tang (2022), musculoskeletal disorders, or MSDs, phrase used to describe a variety of disorders affecting the human locomotor system. One of the key concerns in ergonomics science is the assessment and evaluation of risk factors for musculoskeletal disorders, awkward posture, lifting and transporting objects, repeated motions, vibration, excessive force, contact pressure, low temperature, and inadequate lighting are examples of mechanical and physical risk factors (Abedini et. al, 2012).

Numerous studies have identified construction workers as one of the high-risk groups for MSDs. According to S. Anwer et. al (2021), Numerous psychosocial (such as high job demands and stress) and physical (such as awkward postures, MMH, and prolonged work) risk variables were strongly linked to WRMSDs in construction workers. Bricklayers and concrete workers are especially vulnerable due to frequent lifting, bending, and awkward postures (Boschman et al., 2013). The physical characteristics of bricks and concrete blocks, including their high density and irregular shapes, contribute to excessive physical strain during lifting. Antwi et al. (2021) examined the effects of a passive back-supporting exoskeleton on construction workers who handled heavy objects repeatedly. Compared to lifting without assistance, there was a noticeable decrease in muscle fatigue and a ~30% reduction in lumbar compressive force. found that repeated lifting of objects heavier than 20 kg, particularly when done without mechanical aids, significantly increases spinal compression forces, leading to lumbar spine injuries. Tasks involving twisting while lifting, or working on uneven terrain, further increase the biomechanical load on the body (Gallagher & Heberger, 2013).

Heavy lifting and carrying demand a lot of muscular force. Muscle fatigue and acute overload could result from this. When big bricks are repeatedly handled during building, the skeletal system experiences significant stress. A worker's functional capacity and load-weight relationship determines their risk of developing musculoskeletal problems, supported by Kadota JL, et al (2020), who showed evidence of a significant prevalence of MSDs across all body sites assessed, and a correlation between back pain and related impairment and several load-carrying parameters, including weight, frequency, and duration. Multivariable models showed that increased load-carrying exposures were associated with low back pain (LBP) and related impairment. MSDs related to lifting bricks and concrete commonly affect the lower back, shoulders, and wrists. Concrete pouring and block lifting were also linked to shoulder tendinitis and wrist strain (Slamar, 2023). Recent research indicates a high prevalence of MSDs among bricklayers and construction workers involved in lifting tasks. According to a Nigerian study, the shoulders (61.0%) and lower back (59.3%) were the most affected areas, with a 12-month prevalence of work-related MSDs of 87.3% (Adesoji et. al, 2022). The lower back was the most often afflicted area, with 65.6% of brick industry workers reporting pain and discomfort that lasted at least 24 hours during the previous year, according to a study conducted in Sri Lanka (Fernando et.al, 2016).

The literature identifies several risk factors related to heavy load handling in construction, such as poor posture during lifting or carrying, frequent repetition of lifting tasks, inadequate rest breaks, lack of ergonomic tools or lifting aids, poor worksite layout, requiring excessive bending or twisting, worker fatigue, and physical fitness. Vos et al. (2012) emphasized that the combination of biomechanical overload and environmental factors significantly increases the risk of developing MSDs. The effects of musculoskeletal discomfort can be severe, ranging from chronic pain and functional impairment to permanent disability. For construction workers, this often means being unable to continue in their trade, leading to loss of income and quality of life. For employers, MSDs result in higher medical costs, insurance premiums, and labor turnover.

3.0 METHODOLOGY

3.1 Description of Musculoskeletal Survey/Assessment Method

One important tool used in this study was a questionnaire that included several sections from the 2017 Guidelines on Ergonomics Risk Assessment at Workplace. The questionnaire's first section asked about working experience, medical history, and sociodemographic background. The Cornell Musculoskeletal Discomfort Questionnaire was used to gather information about musculoskeletal aches, pains, or discomforts. Section 2 also featured a body diagram. Musculoskeletal assessment was conducted using the Cornell Musculoskeletal Questionnaire, which was created by Dr. Alan Hedge and graduate students studying ergonomics at Cornell University. As can be seen below, it was discovered that the score was weighted to indicate the most prevalent concerns.

A: During the last work week, how often did you experience aches, pain, or discomfort in:

Table 1
A weighted score based on the most recent job experience that frequently resulted in aches, pain, and discomfort.

Item	Weight
Never	0
1 – 2 times/ week	1.5
3 – 4 times/ week	3.5
Everyday	5
Several times every day	10

B: If you experienced ache, pain, discomfort, how uncomfortable was this?

Table 2
A weighted score based on how uncomfortable the aches, pains, and discomforts are.

	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable
Discomfort score	1	2	3

C: If you experienced ache, pain, or discomfort, did this interfere with your ability to work?

Table 3
A weighted score based on the extent to which aches, pains, and discomforts interfered with work performance.

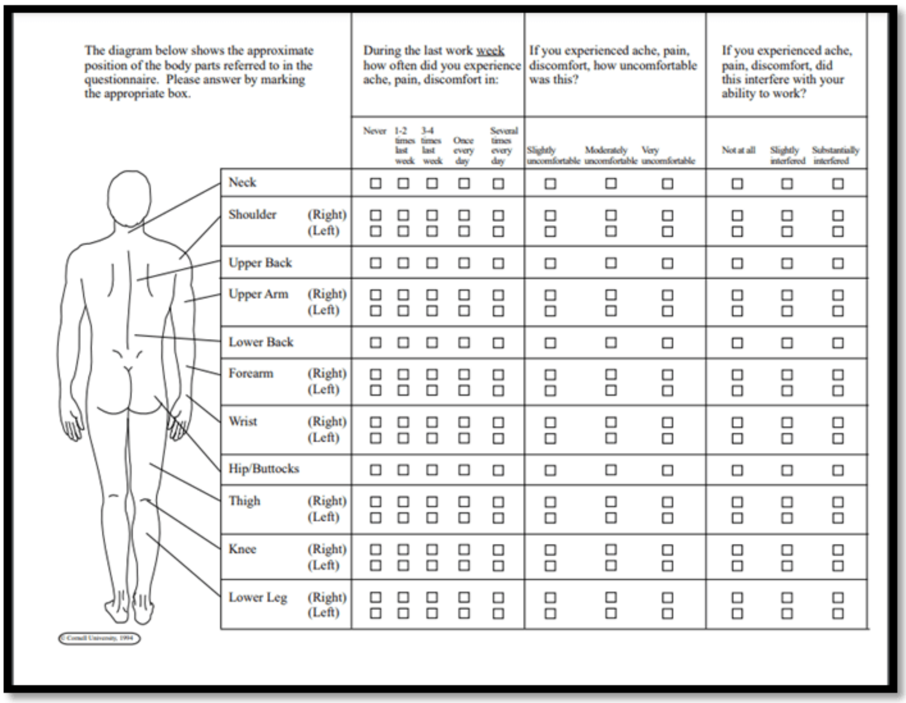
	Not at all	Slightly Interfered	Substantially interfered
Interference Score	1	2	3

This formula is used to determine the severity.

Equation 1: Severity = (A) X (B) X (C)

The data findings were analyzed using Microsoft Excel, which was also used to create the graphs.

Using the Cornell questionnaire, symptoms were evaluated on 12 body parts: the neck, shoulder, upper and lower back, upper arm, forearm, wrists, hip/buttocks, thighs, knees, lower legs, and feet.



The diagram below shows the approximate position of the body parts referred to in the questionnaire. Please answer by marking the appropriate box.		During the last work week how often did you experience ache, pain, discomfort in:					If you experienced ache, pain, discomfort, how uncomfortable was this?			If you experienced ache, pain, discomfort, did this interfere with your ability to work?		
		Never	1-2 times last week	3-4 times last week	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 1: Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)

3.2 Description of Initial Ergonomics Risk Factors Assessment Method

The Initial Ergonomic Risk Assessment (ERA) Form Checklist, which included risk factors, was the last section of the questionnaire. The approach for the ergonomic risk factors was assessed based on 6 key features:

1) Awkward posture
2) Static and sustained work posture
3) Forceful exertion
4) Repetitive motion
5) Vibration: hands-arm and whole body
6) Environmental risk factors:
   a. Lighting
   b. Temperature
   c. Ventilation
   d. Noise

The checklist was designed to identify the risk variables that the lab workers were likely to encounter. Not only that, but photos and videos were also shot while the lab workers worked. Every photo and video that was shot was utilized to support the study's observation. During the interview, each respondent received a briefing and explanation of the questionnaire, enabling them to help fill it out by indicating how often they perform daily work activities that cause aching, pain, or discomfort in any part of their body. Data were retrieved and analyzed following the completion of the questionnaire by the chosen respondents.

Numerous steps are frequently included in the process, which assesses how the worker, their job, and the environment interact. examining and assessing employees' work in its natural setting. Highlight the following important risk factors:

a) Awkward posture

The checklist in Table 3.1 of DOSH's 2017 Guidelines on Ergonomics Risk Assessment at Workplace should be used to examine employees' work posture. Audio-visual and photographic recording devices should be used to capture images from various perspectives, such as the front, rear, and sides.

b) Repetitive motion

Performing the same movement or series of movements repeatedly over time with the same body components is known as repetitive motion, especially when it involves awkward postures or force.

c) Ergonomics risk factors: Forceful exertion (manual handling)

Forceful tasks that call for employees to use a lot of force, like pushing or lifting. When assessing forceful effort, one should consider the weight of objects or the force applied to different activities or manual handling chores. If the manual handling task requires frequent lifting and/or lowering, the suggested weight limit, as shown in Table 4 with reference to Figure 2, might be advised.

Table 4
The recommended weight limit for lifting and/or lowering with the repetitive operation.

If the employee repeats operations	Weight * should be reduced by
Once or twice per minute	30%
Five to eight times per minute	50%
More than 12 times per minute	80%

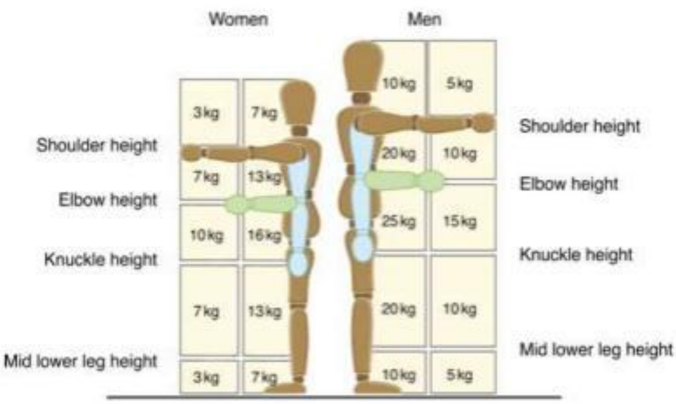


Figure 2: Recommended weight

4.0 DATA ANALYSIS AND FINDINGS

a) Musculoskeletal Survey/Assessment Findings

For this study, the Cornell Musculoskeletal Questionnaire was utilised. The questionnaire showed the assessment finding the respondents feel in the body parts anguish, pain and discomfort. Five respondents were chosen for this evaluation; they were all the ones who answered the body discomfort questionnaire during the previous workweek. Every day, lab participants reported feeling somewhat to moderately uncomfortable, mostly in the lower back and shoulder. The survey was conducted from Appendix 1, which is a respondent-filling-in self-assessment Musculoskeletal pain/ discomfort survey form. Respondent was instructed to fill Appendix 2 ergonomic and musculoskeletal pain/ discomfort complaint form. The acquired data (Appendix 3) are displayed in Table 5.

Table 5
Cornell Musculoskeletal Questionnaire

Respondent	Body Parts	Frequency (a)	Discomfort (b)	Interference (c)	Severity a x b x c
1	Shoulder (left)	1.5	2	2	6
	Knee (right)	1.5	2	2	6
	Knee (left)	1.5	2	2	6
2	Shoulder (left)	1.5	1	1	1.5
	Lower back	1.5	3	2	9
3	Upper arm	3.5	3	3	31.5
	Upper back	3.5	1	2	7
	Lower back	3.5	2	2	14
4	Shoulder (right)	3.5	1	2	7
	Upper back	1.5	3	2	9
5	Shoulder (left)	1.5	1	1	1.5
	Lower back	1.5	2	2	6

The Cornell Musculoskeletal Questionnaire's score results are computed by multiplying the discomfort and interference scores (1, 2, 3) by the frequency scores (0, 1.5, 3.5, 5, 10). Figure 3 shows the summary of Appendix 3.

b) Ergonomics Risk Factors Assessment Findings (Initial ERA)

In addition to the evaluation of the musculoskeletal system, an ergonomic risk factor was also noted and seen while the respondents worked. The five ergonomic risk factors that are related to work activities involving awkward posture, static and sustained work posture, forceful exertion, repetitive motion, and environmental factors are the focus of the ergonomic risk factors data that was observed and analysed using the Initial Ergonomic Risk Assessment Checklist.

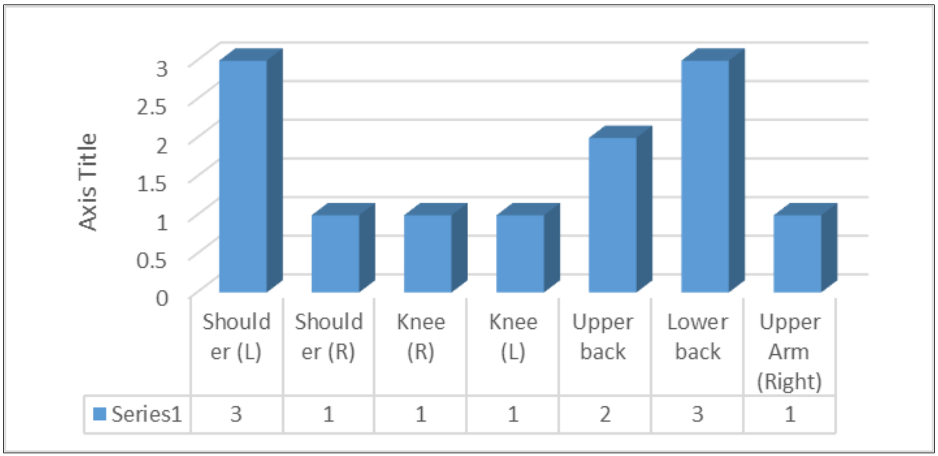


Figure 3: Discomfort and pain reported by workers

Appendix 6 has led to the identification of the following ergonomic issues: -

a) Ergonomics risk factors: Awkward Posture
b) Ergonomics risk factors: Static and Sustained Work Posture
c) Ergonomics risk factors: Forceful Exertion
d) Ergonomics risk factors: Repetitive motion
e) Ergonomics risk factors: Vibration
f) Ergonomics risk factors: environmental factors
a) Ergonomics Risk Factors: Awkward Posture

Table 6 shows ergonomic risk factors involved with awkward posture. Three physical risks were identified based on observation: working with the head bent down more than 45 degrees, the back bent forward more than 30 degrees, or the sideways, and working with the wrists flexed, extended, or radially deviated more than 15 degrees.

Table 6
Ergonomics Risk Factors: Awkward Posture

Body Part	Physical Risk Factor	Max. Exposure Duration	Please tick (/)		Activities/ remark
			Yes	No	
Shoulders	Work with the hand above the head OR the elbow above the shoulder	More than 2 hours per day		/	
	Work with your shoulder raised	More than 2 hours per day		/	
	Work repetitively by raising the hand above the head OR the elbow above the shoulder more than once per minute	More than 2 hours per day		/	

Body Part	Physical Risk Factor	Max. Exposure Duration	Please tick (/)		Activities/ remark
			Yes	No	
Head	Work with the head bent downwards more than 45 degrees	More than 2 hours per day	/		
	Work with the head bent backwards	More than 2 hours per day		/	
	Work with your head bent sideways	More than 2 hours per day		/	
Back	Work with bent back forward more than 30 degrees OR bent sideways	More than 2 hours per day	/		
	Work with the body twisted	More than 2 hours per day		/	
Hand/ Elbow/ Wrist	Work with wrist flexion OR extension, OR radial deviation of more than 15 degrees	More than 2 hours per day	/		
	Work with arm abduction sideways	More than 4 hours per day		/	
	Work with arm forward more than 45 degrees OR arm backward more than 20 degrees	More than 2 hours per day		/	
Leg/knees	Work in a squat position	More than 2 hours per day		/	
	Work in a kneeling position	More than 2 hours per day		/	
Subtotal (number of tick (s))			3	10	

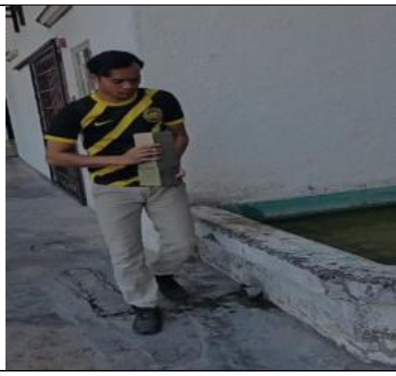
Table 7 shows no static and sustained work posture because the task requires the respondent to walk from the curing pond to the testing machine.

Table 7
Ergonomics Risk Factors: Static and Sustained Work Posture

Body Part	Physical Risk Factor	Max. Exposure Duration	Please tick (/)		Activities/ remark
			Yes	No	
Trunk/ Head/ Neck/ Arm/ Wrist	Work in a static awkward position as in Table 3.1	Duration as per Table 3.1		/	
Leg / Knees	Work in a standing position with minimal leg movement	More than 4 hours per day		/	
	Work in a seated position with minimal movement	More than 2 hours per day		/	
Subtotal (number of tick (s))			0	3	

The task of lifting samples from the curing pond is displayed in Table 8. They basically handle three to five samples by hand. A cube's mass, according to British Standards (BS 1881-108), is 8.1 kg. According to the observation, the respondent carried three samples totaling 24.3 kg in weight. Weight reduction of 30% is advised, as the task involves repetitive operations and is consumed once or twice per minute; the recommended weight limit is 16.8 kg, which exceeds the limit.

Table 8
Ergonomics Risk Factors: Forceful Exertion: (Manual handling – Lifting and/ or lowering)

Working Height (Where force is Applied)	Recommended Weight Limit (Male or Female)	Current weight Handled	Exceed limit?		Activities/ remark
			Yes	No	
Between the floor and to mid lower leg				/	
Between the mid-lower leg and to knuckle				/	
Between knuckle height and elbow	24.-3 kg – 30% = 16.8 kg	3 x 8.1 kg = 24.3 kg	/		

Working Height (Where force is Applied)	Recommended Weight Limit (Male or Female)	Current weight Handled	Exceed limit?		Activities/ remark
			Yes	No	
Between the elbow and the shoulder				/	
Above the shoulder				/	
Subtotal (number of tick (s))			1	4	

This activity also includes carrying activity, which is a lab technician's need to carry the sample to the testing machine. From the summary, for carrying activity needs to be conducted in advance ERA because the area of curing pond is wet and in poor condition.

Figure 4: Condition area curing pond

Table 9 shows ergonomic risk factors: Repetitive motion. This task is related to repetitive motion, which requires the respondent to carry the sample according to the sample batch. There are 3 physical risk factors identified in this task.

Table 9

Ergonomics Risk Factors: Repetitive motion

Body Part	Physical Risk Factor)	Max. Exposure Duration	Exceed limit?		Activities/ remark
			Yes	No	
Neck, shoulders, elbows, wrists, hand, knee	Work involving repetitive sequence of movement more than twice per minute	More than 3 hours on a “normal” workday	/		Because they had to complete the work in accordance with the research and consultation, the worker engaged in repetitive motion. The testing is scheduled and scheduled according to student and lecturer availability.
	Work involving intensive use of the fingers, hands, or wrist, or Work		/		

Body Part	Physical Risk Factor)	Max. Exposure Duration	Exceed limit?		Activities/ remark
			Yes	No	
	involving intensive keying	OR			
	Work involving repetitive shoulder/arm movement with some pauses OR continuous shoulder/arm movement	More than 1 hour continuously without a break	/		Because they had to complete the work in accordance with the research and consultation, the worker engaged in repetitive motion. The testing is scheduled and scheduled according to student and lecturer availability.
	Work using the heel/base of palm as a "hammer" more than once per minute	More than 2 hours per day		/	
	Work using the knee as a "hammer" more than once per minute	More than 2 hours per day		/	
Subtotal (number of tick (s))			3	2	

5.0 DISCUSSION AND CONCLUSIONS

The body parts in this study where WMSDs were most common were the upper back, lower back, shoulders, upper arm, and knee. In comparison, the hips and buttocks were the least affected body parts. The following factors are probably to blame for the workers' discomfort: (1) repetition, and (2) heavy force exertion. The summary of the first ERA's results is displayed in Table 10.

When considering advanced ergonomic risk assessment (ERA) methods for forceful exertion and repetitive motion, there are several strategies and tools that can be implemented to better evaluate and mitigate risks. Here's a comprehensive overview:

a) Risk Assessment Models
   i. RULA (Rapid Upper Limb Assessment): Use RULA to evaluate postural risks associated with upper limb tasks, focusing on force and repetition.
   ii. REBA (Rapid entire body assessment): ergonomic evaluation tool designed to assess the risk of musculoskeletal disorders (MSDs) in tasks involving awkward postures, repetitive motions, and physical strain across the entire body.
   iii. Manual Handling Assessment Chart (MAC): Assess the most common risk factors in lifting, lowering, carrying, and team handling operations. The tool was developed to identify high-risk manual handling.

Table 10
Summary of Results from Initial ERA

Risk Factor	Total score	Minimum Requirements for Advance ERA	Result of Initial ERA	Any pain or discomfort due to risk factors as found in MSD assessment	Need advanced ERA (Yes/No)
Awkward posture	13	≥ 6	3	If YES please tick which part of body	No
Static and sustained work posture	3	≥ 1	0		No
Forceful exertion	1	1	1		Yes
Repetition	5	≥ 1	3		Yes
Vibration	4	≥ 1	0		No
Lighting	1	1	0		No
Temperature	1	1	0		No
Ventilation	1	1	0		No
Noise	2	≥ 1	0		No

Neck	
Shoulder	Yes
Upper back	Yes
Upper arm	Yes
Lower back	Yes
Forearm	
Wrist	
Hand	
Hip/buttocks	
Thigh	
Knee	Yes
Lower leg	
Feet	

Based on the discussed causes of discomfort, there is a need to propose control measures to minimize the WMSDs among material handlers in the concrete laboratory, the following controls are proposed in this study.

a. Use Proper Lifting Techniques: Encourage workers to bend their knees and lift with their legs rather than their back.
b. Mechanical Aids: Use tongs or hoists to lift the cubes, reducing the manual effort needed.
c. Reduce Repetition: Rotate tasks among workers to avoid repetitive strain injuries.
d. Slippery Surface Control: Ensure the area around the curing pond is slip-resistant

An initial ergonomic risk assessment in handling concrete cubes is essential to identify hazards like awkward postures, repetitive movements, and forceful exertion, which can cause musculoskeletal issues. Early intervention through ergonomic solutions—such as workstation redesign, task automation, and lifting aids—helps prevent injuries, improve worker health, reduce absenteeism, and enhance productivity. Investing in ergonomics fosters a safer workplace and boosts overall organizational efficiency.

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