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Improving Workplace Safety: An Ergonomic Assessment and Engineering Control Approach

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ABSTRACT

Workplace injuries in machining departments, particularly back pain from manual handling, reduce productivity and increase manpower shortages. This study aimed to identify the root causes of these injuries and propose an engineering control solution through the Plan-Do-Check-Act (PDCA) cycle. Hazard Identification, Risk Assessment, and Risk Control (HIRARC), Ishikawa diagram analysis, and ergonomic assessment using the Rapid Entire Body Assessment (REBA) were applied to evaluate existing practices. The findings showed that lifting cutting tools from low storage racks produced a high REBA score of 9, indicating a high risk of musculoskeletal disorders. A new ergonomically designed storage rack concept was developed and evaluated using CATIA V5 software, with three alternatives compared through a Pugh Chart. Design B, which eliminated the need for trunk bending, was selected. Reassessment revealed that the REBA score decreased from 9 to 2, while the risk score for back pain was reduced from 12 to 3, achieving a 75% risk reduction. These improvements demonstrate a significant enhancement in workplace safety, reducing injury risks and improving productivity. The study highlights how ergonomic interventions integrated with the PDCA framework can provide practical solutions for minimising occupational hazards and ensuring sustainable productivity.

Keywords: Workplace injuries; PDCA cycle; HIRARC; Ergonomic assessment; REBA

1.0 INTRODUCTION

Workplace safety has long been recognised as a critical priority in the manufacturing industry, where the primary aim of safety measures is to create an environment that minimises hazards and promotes the health and well-being of employees. Effective safety procedures focus on identifying, evaluating, and eliminating potential risks to prevent worker exposure to harmful situations [1]. Poor workplace safety not only results in injuries but also reduces productivity, increases operational costs, and contributes to employee dissatisfaction.

Musculoskeletal disorders (MSDs) represent one of the most common occupational health concerns in manufacturing environments. Research has shown that improper working posture, repetitive movements, and awkward body positions are significant contributors to MSDs among maintenance and production workers [2], [3], [4]. These disorders are frequently associated with poorly designed workstations and insufficient ergonomic considerations. In addition to ergonomic risks, workplace hazards can stem from equipment, hazardous materials, unsafe practices, and unsafe human behaviour. If not addressed, each of these factors can lead to injuries, illnesses, or even fatalities [5]. Recognising these risks and implementing appropriate control strategies is therefore essential in establishing a safe and sustainable work environment.

Many organisations focus on administrative controls and personal protective equipment (PPE) to manage risks. These include safety training, supervision, and protective gear. While these measures are important, they often do not fully eliminate hazards at their source. Consequently, administrative controls and PPE should be viewed as supplementary measures rather than the primary means of defence [6]. This highlights a significant gap in workplace safety practices: the underutilization of engineering controls. These controls offer sustainable and long-term solutions by redesigning equipment, tools, or workstations to reduce risk exposure. To address this gap, structured methodologies are needed that not only identify risks but also guide the implementation of engineering interventions.

To address safety concerns in a structured and continuous manner, the Plan-Do-Check-Act (PDCA) framework offers a systematic approach for problem-solving and process improvement. This framework allows organisations to identify hazards, implement targeted interventions, evaluate outcomes, and refine safety strategies. For example, Balubaid and Basahel [7] demonstrated that the application of PDCA in the Saudi cargo sector significantly improves workplace safety through systematic hazard identification and corrective action planning.

This research was conducted at a multinational company located in Penang, Malaysia, that specialises in the production of electronic and industrial products. The study was initiated following a formal complaint made to

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the supervisor, which prompted an investigation to identify a specific area in need of intervention. The assessment focused on the machining department, particularly the milling process, where workers are exposed to risks from high-speed rotating tools, sharp cutters, and prolonged exposure to loud noise. Unsafe practices in this department can lead to injuries, long-term health issues, manpower shortages, and decreased productivity, underscoring the need for a structured safety intervention.

The objective of this research is fourfold: first, to identify areas within the machining department that are prone to risk; second, to assess the associated hazards and their levels of risk; third, to propose appropriate engineering and organizational changes aimed at mitigating these risks; and finally, to evaluate the effectiveness of the implemented changes in reducing workplace hazards and improving employee safety.

2.0 METHODOLOGY

2.1 Structure of the research

To achieve the objective, this study used the PDCA framework as the basis of the identification of hazards, implementation of targeted interventions, evaluation of outcomes, and refining safety strategies. The PDCA cycle, initially formulated by Dr. W. Edwards Deming, represents a systematic methodology for managing workplace hazards and promoting continuous improvement [8]. The process comprises four fundamental phases: Plan, Do, Check, and Act, which together establish a systematic and repetitive approach for recognising potential dangers, executing preventive measures, evaluating effectiveness, and fostering a culture of continuous improvement. Table 1 outlines the steps of the PDCA cycle that are undertaken sequentially to address the issues in the machining department.

Table 1: PDCA Cycle Flow Process

PDCA	Step	Stage	Methods and Techniques	Goals
Plan	1	Problem identification	• Observation	• Identify the hazards that occur from the work activities in the machining area.
	2	Data collection	• Interview • HIRARC	• Analyse the risk score for the hazards.
	3	Data analysis	• Ishikawa diagram • Initial ergonomic assessment	• Examine and identify the root cause of the work accidents.
	4	Action Plan	• Hierarchy of Control	• Develop preventative measures that can be used to overcome the identified hazards.
Do	5	Materials Selection	• Market research	• Finding the materials to apply for making the new equipment. • Gain the idea based on the current equipment.
	6	Design	• CATIA V5 Software • Pugh Chart	• Propose three designs of new equipment. • Choose the suitable design that meets the requirements.
Check	7	Assessment	• Ergonomics assessment • HIRARC	• Reassess and compare the result for before and after improvement including cost of accident.
Act	8	Standardization	• Standard operating procedure (SOP)	• Prioritize the safety precautions for further steps.

This study adopted the Plan-Do-Check-Act (PDCA) cycle as a structured framework for improving workplace safety in the machining department. The methodology is presented according to the four phases of the PDCA cycle, as summarised in Table 1.

Plan Phase: The objective of the Plan phase was to identify potential hazards in the machining department. This was accomplished through direct observations, interviews with the department supervisor, and a review of accident records. The current work was analysed using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method to identify the workstations or tasks that contributed to the most common injuries. To further investigate the causes, the Ishikawa Diagram was employed for root cause analysis. Additionally, ergonomic risks were assessed using tools such as the Rapid Entire Body Assessment (REBA), which are widely recognised for identifying high-risk postures and repetitive tasks that contribute to musculoskeletal disorders. The REBA assessment method has been successfully applied in industries such as food delivery [9], waste handling [10], and manufacturing [11]. Based on the findings, preventive measures were formulated using the Hierarchy of Control as the action plan.

Do Phase: In the Do phase, the action plan was implemented. Following the Hierarchy of Control, we chose an engineering control, specifically the design of a new storage rack, to address the identified injury risks. The design criteria took into account ergonomics, safety, durability, functionality, and efficiency. To support this process, the specifications of the current equipment were analysed, and market research was conducted to identify suitable materials. Three design alternatives were proposed, and the most appropriate design was selected using a Pugh Chart evaluation.

Check Phase: The Check phase concentrated on assessing the effectiveness of the implemented solution. Risk assessments were conducted again using the REBA and HIRARC method, and the new results were compared with the baseline data. This evaluation determines how effectively the intervention reduces the identified hazards and ensures that the new design enables workers to perform tasks more safely and productively.

Act Phase: The Act phase brought together the improvements that had been implemented. During this phase, recommendations were made to standardise the standard operating procedures (SOPs) for using the new equipment. Additionally, it was suggested to hold training and awareness sessions to ensure proper usage. By adopting these practices, the company can sustain the risk reductions achieved and prevent future work-related injuries.

3.0 RESULTS AND DISCUSSION

3.1 Plan phase

The research began following a formal complaint submitted to the supervisor, which led to an investigation. This investigation identified a specific area that requires intervention: the milling process in the machining department. Subsequently, an observation period was implemented in which workers' activities and workplace conditions were closely monitored to identify potential safety issues. In total, workers performed ten different activities to operate the milling process. These activities are detailed in Table 2, which categorise the injury risk as low, moderate, or high. Through interviews with the supervisor and observations of the workstation, five activities in the work process were identified as potential causes of injury within the department.

The risk assessment employs the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method to analyse the hazards and risks associated with these five activities that can lead to injury. Risk assessment is a qualitative method that utilises a likelihood and severity table to calculate the risk score for the five activities. The initial risk assessment is presented in Table 3.

Based on the risk assessment, the primary risk in the machining department is back pain resulting from manual handling when lifting cutting tools from the storage rack. The lifting of cutting tools in this department has introduced an ergonomic risk, which contributed to the onset of back pain and other musculoskeletal disorders. Improper body mechanics and lifting techniques are the main factors contributing to the ergonomic risks linked to lifting cutting tools. When workers lift the cutting tools without employing appropriate lifting techniques, they place an excessive amount of strain on their back muscles [12].

Table 2: Work processes in the machining department

	No	Activity	Quantity (unit)	Distance (m)	Time/ unit (min)	Operation	Transportation	Inspection	Delay	Storage	Remarks
Machining (CNC Machine)	1	Pick up raw materials at the inventory using an electric motor jack	1	200	30						Low injury
	2	Ties the raw material using a chain	-	-	15						No injury
	3	Lift raw material using crane	-	-	30						No injury
	4	Lift the cutting tools from the storage rack	10	10	5						High injury
	5	Setup the cutting tools on the machine	-	-	10						Moderate injury
	6	Setup raw material on the machine	-	-	120						Low injury
	7	Check the cutting tool for every program	-	-	5						Low injury
	8	Hold the cutting tool	-	-	5						No injury
	9	Untie the final product	-	-	25						No injury
	10	Remove the final product	-	-	5						No injury
		Total	**11**	**210**	**250**	**5**	**3**	**1**	**1**	**0**	

When the major risk has been identified, the primary causes of the identified risk were analysed through the data analysis process. Data analysis is the process of systematically examining and interpreting collected data to gain a deeper understanding of the problem and its root cause. The Ishikawa Diagram (Figure 1) is utilised as a tool to facilitate comprehensive analysis, which can encompass various aspects such as determining the effects of an accident and exploring all potential causes [13]. It is a versatile tool for analysing the causes of back pain that occur in the machining department. The method proves to be highly effective in addressing issues that involve a series of interconnected causes.

After identifying all the factors that contribute to the occurrence of back pain, it is possible to understand the most crucial factor. Based on observation, the height of the storage rack emerged as the most significant factor contributing to the occurrence of back pain.

To assess the risk level, an initial ergonomic assessment was conducted using the Rapid Entire Body Assessment (REBA) method to analyse and score the postures and movements of various body parts while lifting the cutting tools. The REBA framework provides a systematic approach for effectively evaluating ergonomic hazards and prioritising interventions based on the severity of the identified risks [14]. The current posture of workers when lifting cutting tools from the storage rack is shown in Figure 2, created using CATIA V5 software. This positioning is based on the cutting tool at the lowest tier of the rack.

Table 3: Initial risk assessment

No	Work Process	Hazard	Risk	Likelihood	Severity	Score
1.	Lift the cutting tools from the storage rack.	Body bending	Back pain	4	3	12
2.	Setup cutting tools on the machines.	Sharp cutting tools.	Hand injury	2	3	6
3.	Setup the raw materials on the machine.	Walked on the slippery floor on the machines.	Slip and fall	2	2	4
4.	Pick up raw material using electric pallet jack.	Unable to stop immediately due to heavy raw materials.	Struck	1	2	2
5.	Check the cutting tools for every program.	Expose to the hot surface during checking the tools.	Skin burns	1	1	1

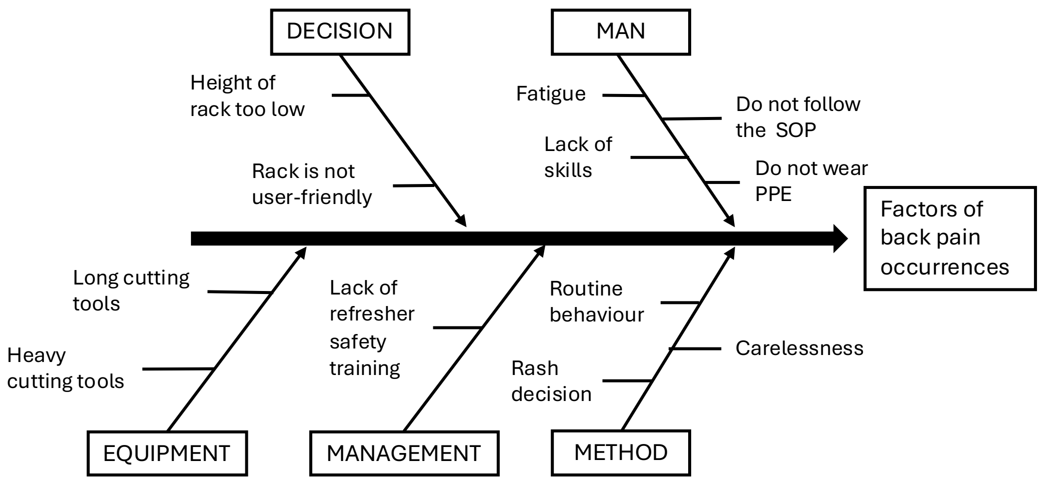


Figure 1: Ishikawa Diagram for identifying the root cause of back pain

The neck is positioned at 10˚ to 20˚ forward (+1), resulting in a total score of 1 (Figure 3(a)). The trunk is bent forward between 20˚ and 60˚ (+3), with the trunk side bending according to the situation (+1). The total score for trunk position is 4 (Figure 3(b)). The legs and feet are supported (+1) with adjusted position (+2), giving a score of 3 (Figure 3(c)). Based on the score gathered, the total score for neck, trunk and leg was looked up from Table A (refer to Table 4). Based on the score combination, the gathered trunk posture score is 6. The total score is added with the force or load being considered between 11 to 22 lbs (+1). This results in a total score of 7.

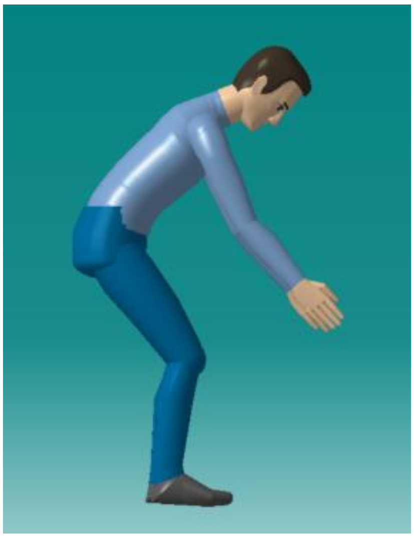
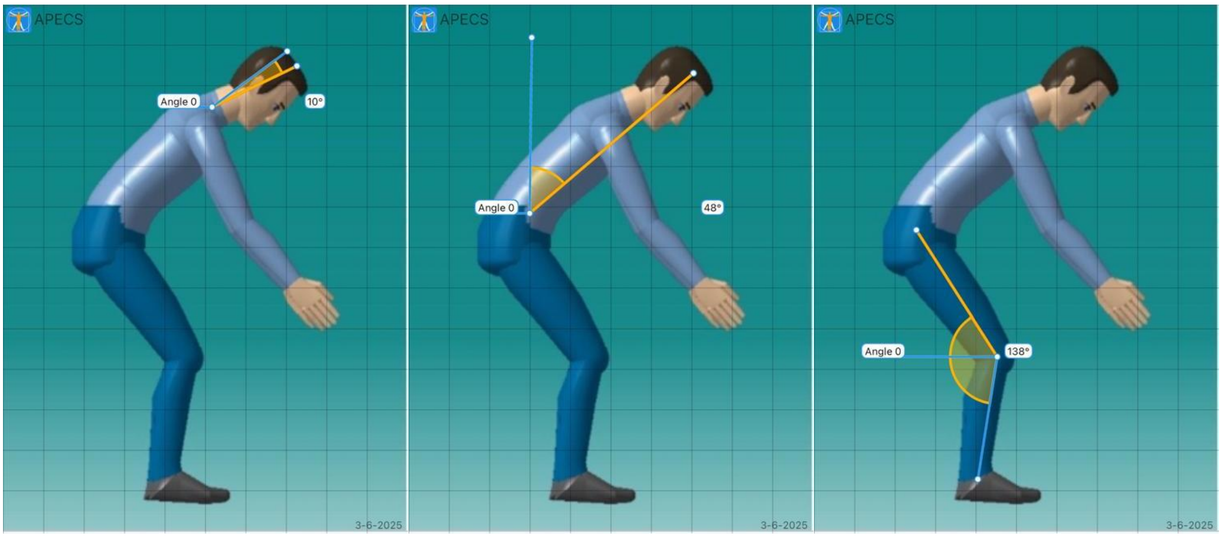


Figure 2: Current body posture of workers



(a) (b) (c)

Figure 3: REBA neck, trunk and leg analysis

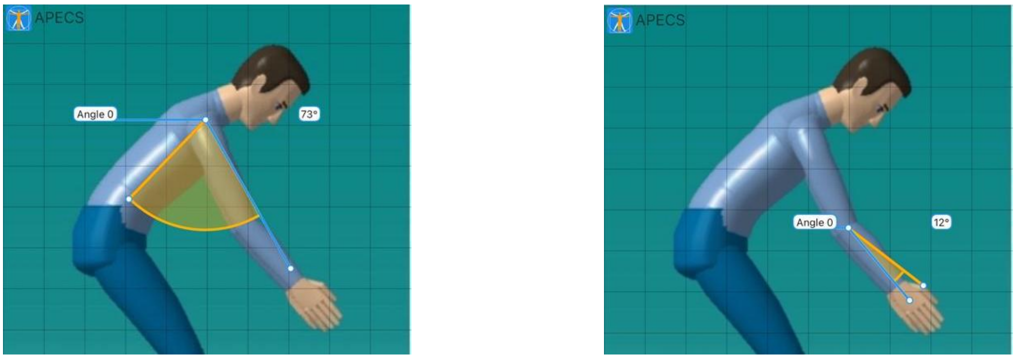
Table 4: Trunk Posture Score

		Neck											
Table A		**1**				2				3			
	Legs	1	2	**3**	4	1	2	3	4	1	2	3	4
	1	1	2	3	4	1	2	3	4	3	3	5	6
Trunk	2	2	3	4	5	3	4	5	6	4	5	6	7
Posture	3	2	4	5	6	4	5	6	7	5	6	7	8
Score	**4**	3	5	**6**	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Based on the assessment of the upper arm position in Figure 4(a), the arm is positioned between 20˚ to 45˚ (+2), and the shoulder is raised (+1). The upper arm position score is 3. The lower arm is positioned between 0˚ to 60˚ with a score of 2 (Figure 4(b)). The wrist flexes less than 15˚, scoring 1 for wrist position.

Based on the scores gathered, the total score for arm and wrist posture scores was looked up from Table B (refer to Table 5). The gathered arm and wrist score is 4 based on the score combination. The coupling score component is 0 because the tool has a well-fitting handle and mid-range power grip. This gathers a total score of 4.

The REBA total score is categorised into four levels of risk based on the score range. A score between 1 and 4 indicates a low risk, suggesting minimal risk of musculoskeletal disorders (MSDs). Scores ranging from 4 to 7 fall under the medium risk category, which implies the need for further investigation and potential ergonomic interventions to reduce risk. A score of 8 to 10 is classified as high risk, requiring immediate investigation along with the implementation of control measures to modify the task. Finally, scores between 11 and 15 represent a very high risk, where immediate changes are necessary to reduce strain and prevent MSDs. In the current workstation assessment, the total REBA score is derived from Table C (see Table 6). An additional point was added to the final score because one or more body parts are held in position for longer than one minute (+1). A total score of 9 in the REBA assessment indicates a high risk of musculoskeletal disorders (MSD), prompting a recommendation to investigate and implement changes.



(a) (b)

Figure 4: REBA arm and wrist analysis

Table 5: Arm and Wrist Analysis Score

Table B		Lower arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table 6: REBA total score

Score A	Table C Score B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

3.2 Do phase

There are several techniques that can be used to manage hazards effectively. These techniques are ranked from most effective to least effective: (1) elimination, (2) substitution, (3) engineering controls, (4) administrative controls, and (5) the use of personal protective equipment (PPE). This ranking is known as the hierarchy of control. It is essential to eliminate hazards whenever possible and to ensure a good fit between the job and the worker [3]. This study emphasised the importance of engineering controls to eliminate hazards. Engineering controls involve the process of removing or reducing workplace hazards through the installation of various physical modifications or safety systems [4].

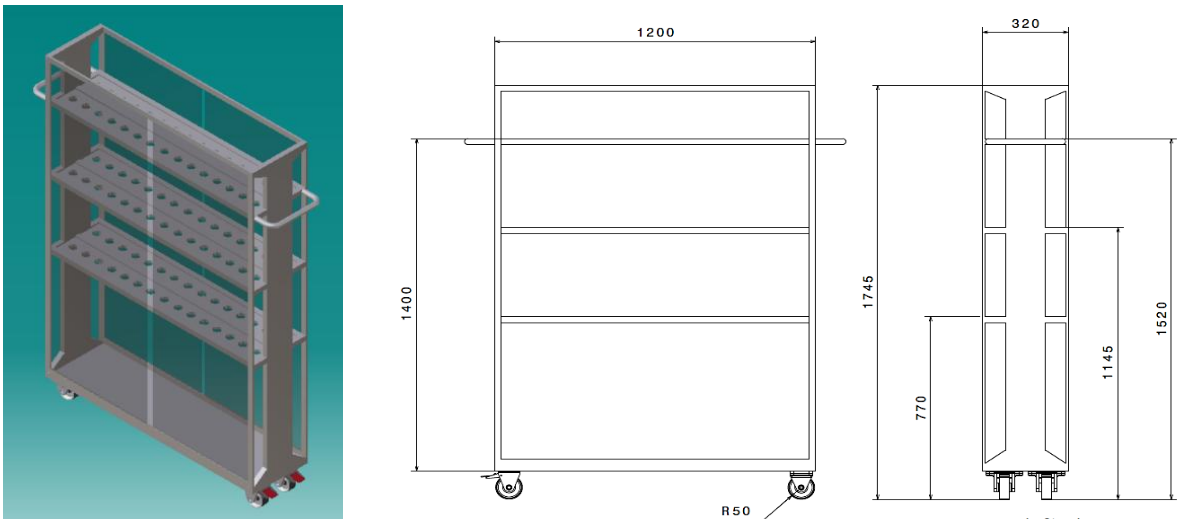
For this case study, substitution together with engineering control was selected as the preventive measure to mitigate the identified problem by designing a new storage rack that meets the necessary requirements concerning ergonomics, safety, durability, functionality, and cost. Past research has shown that engineering control and substation are among the successfully implemented measures to ensure occupational safety and health of workers [4]. In essence, the hierarchy of control is a systematic approach to mitigating hazards by prioritising and implementing control measures in a specific sequence [15].

The design of a new storage rack is the solution that has been considered as the action plan to solve the highest injury rate in the machining department. The initial process of designing a new storage rack began with the selection of materials for the design. The materials selection to be used in a product must meet safety standards and regulations [16]. Based on the market research, the most suitable material to be used for manufacturing a new storage rack is steel due to its strength and durability, which can hold up the heavy equipment. Regarding this study, the average weight of each cutting tool used in the machining department was 4 kg. Thus, steel is the best choice to manufacture a new storage rack.

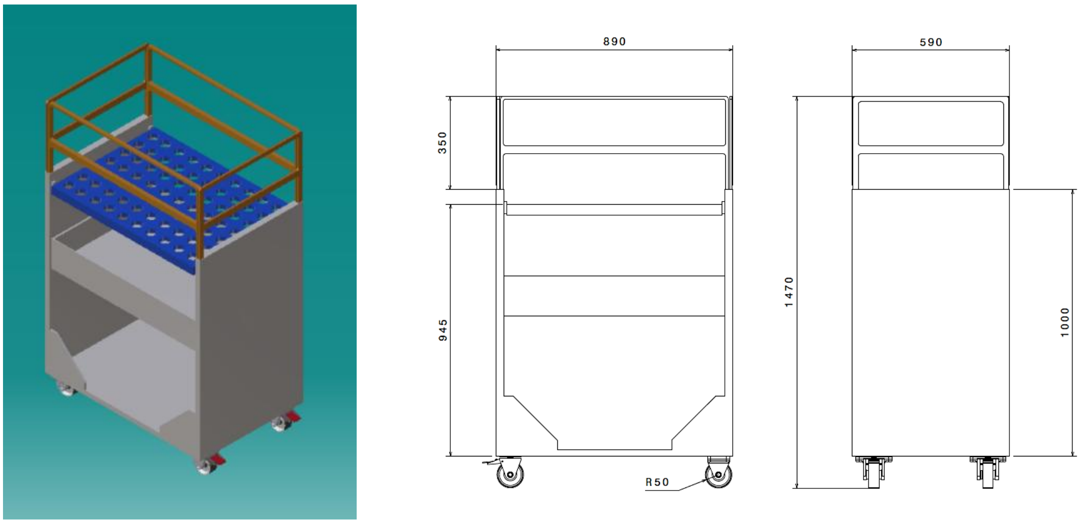
The current storage rack in the department, as shown in Figure 5, was examined to gather ideas for developing an improved storage rack, particularly in terms of ergonomics and safety to prevent workers from sustaining injuries when lifting cutting tools. Referring to the Ishikawa diagram, the height of the storage rack in the department is one of the factors contributing to occurrences of back pain among workers. The recommended height of workbenches is between 95cm and 114cm for medium-class light work [17]. The measurement shows that the current rack's total height was approximately 82 cm (on the highest tier), which is lower than the recommended height. As a result of this, the worker needs to bend down while performing their work when lifting cutting tools.

After reviewing the current design of the storage rack, a new model was created using CATIA V5 software during the design phase. The objective of this phase is to enhance safety and implement strategies to prevent and reduce the likelihood and severity of back pain. The new rack design is unique and requires specific holders for tool tips, making standard commercial racks unsuitable. This approach addresses the distinct characteristics of specific workplaces to improve hazard management [18]. Consequently, we have proposed and designed three new storage racks with different heights and safety features, as shown in Figure 6.

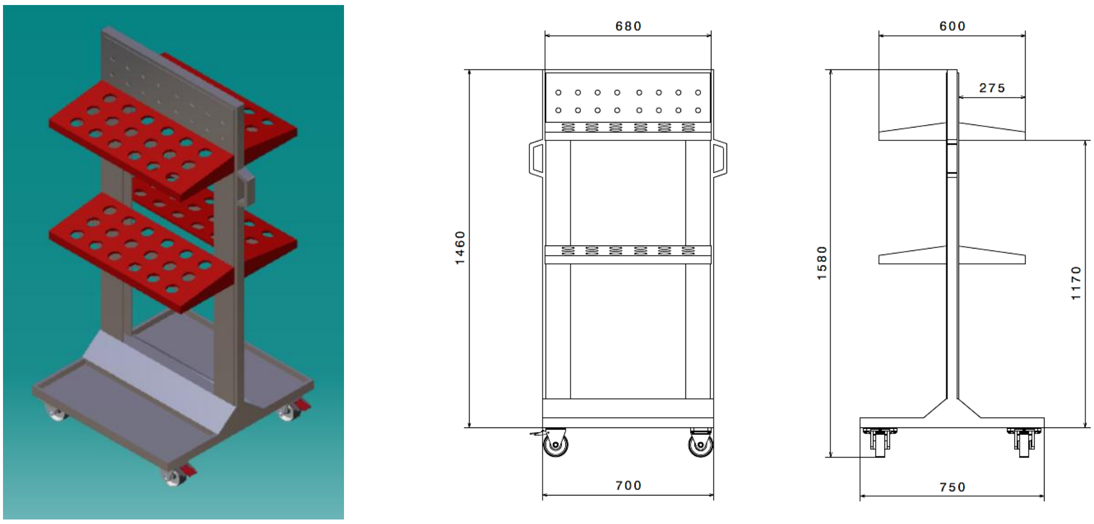
Figure 5: The current storage rack in the machining department



(a) Design A and dimensions



(b) Design B and dimensions



(c) Design C and dimensions

Figure 6: The proposed designs of the new storage rack

Ergonomic testing was conducted to analyse which of the three designs meet the ergonomic requirements. This testing involved examining the body posture of workers when lifting cutting tools from each of the new storage racks. The body posture of workers was structured using CATIA V5 software, as shown in Figure 7. Based on the result, the body posture for design A and design C showed that the workers need to bend their bodies when lifting the cutting tools from the different shelves of the tool holders. This situation could still expose workers to back pain injuries due to the repetitive posture of lifting the tools. Apart from that, design B showed that the workers are no longer required to bend their bodies to lift the cutting tools; instead, they can lift the tools while standing straight, as there is only one shelf of tool holders in design B.

A Pugh chart was used to compare these designs based on the criteria of ergonomics, safety, functionality, durability, cost, and maintenance. According to the analysis (refer to Table 7), design B was chosen as the best design because its net score was the highest among the other designs. This design meets the criteria of ergonomics and safety, effectively addressing back pain issues in the machining department. Additionally, design B offers benefits for the workers, ensuring they are comfortable when using the new storage rack for storing and lifting the cutting tools.

(a) Design A (b) Design B (c) Design C

Figure 7: Ergonomic testing for each design

Table 7: Design comparison through Pugh Chart

Description		Cutting tools storage rack			
Evaluation criteria	**Weight**	**Current**	**Design A**	**Design B**	**Design C**
Ergonomic	3	0	-	+	-
Safety	3	0	+	+	-
Functionality	2	0	0	0	0
Durability	2	0	+	+	+
Cost	2	0	0	0	0
Ease of Maintenance	2	0	+	+	+
Total (+)		0	7	10	4
Total (0)		6	2	2	2
Total (-)		0	3	0	6
Net score		**0**	**4**	**10**	**-2**

3.3 Check phase

The body posture was changed from bending to standing as to lift the cutting tools after design B was selected as the new storage rack in the machining department. In relation to this posture change, an ergonomic assessment was conducted again to reassess the ergonomic score. The score was evaluated using the REBA method, and the comparison of the REBA score before and after the improvements made in the machining department is shown in Table 8.

The neck is positioned at 10˚ to 20˚ forward (+1), resulting in a total score of 1. The trunk is in an upright position (0), with the trunk twisted according to the situation (+1). The total score for trunk position is 1. The legs and feet are supported (+1), giving a score of 1 (Figure 2 (c)). Based on the score gathered, the total score for neck, trunk and leg was looked up from Table A; and the gathered trunk posture score is 1. The total score is added with the force or load being considered between 11 and 22 lbs (+1). This results in a total score of 2.

Based on the assessment of the upper arm position, the arm is positioned between 20˚ (+1), and the shoulder is raised (+1). The upper arm position score is 2. The lower arm is positioned between 60˚ and 100˚ with a score of 1. The wrist flexes less than 15˚, scoring 1 for wrist position. Based on the scores gathered, the total score for arm and wrist posture scores was looked up from Table B. The gathered arm and wrist score is 1 based on the score combination. The coupling score component is 0 because the tool has a well-fitting handle and mid-range power grip. This gathers a total score of 1.

The REBA total score is gathered from Table C. Two activity scores are added to the final score; the first is on one or more body parts that are held for longer than 1 minute (+1). The total score of 2 in the REBA assessment indicates a low risk of MSD, where change may be needed.

The REBA score, as shown in Table 8, indicated that the body posture score for workers lifting cutting tools from the new storage rack was reduced from 9 to 2. The reduction in score demonstrated that the improvement has successfully reduced the risk of back pain among the workers. This shows that the workers are not required to bend their bodies; instead, they can lift the cutting tools whilst standing. The implementation of the new storage rack will reduce the risk of back pain in the machining department. In this case, the risk evaluation was conducted to evaluate the risk after making the improvement. The comparison of risk scores before and after the improvement is shown in Table 9. The emphasis on risk reduction has become a key aspect of implementing ergonomic practices in the workplace [19].

Table 8: Comparison of REBA Score before and after improvement

Group	Body parts and factors	Score	
		Before improvement	After improvement
Table A - Neck, trunk and leg Assessment	Neck	1	1
	Trunk	4	1
	Leg	3	1
	Table A value	6	1
	(+) Load force	1	1
	Total Table A	7	2
Table B - Arm and Wrist Assessment	Upper arm	3	2
	Lower arm	2	1
	Wrist	1	1
	Table B value	4	1
	Coupling	0	0
	Total Table B	4	1
Table C – Total REBA score	**Table C value**	8	1
	Body parts held longer than 1 min	1	1
	Total REBA score	**9**	**2**

Table 9: The comparison of risk scores before and after improvement

No	Work process	Hazard	Risk	Before improvement			After improvement		
				Likelihood	Severity	Score	Likelihood	Severity	Score
1	Lift the cutting tools from the storage rack	Body bending	Back pain	4	3	12	1	3	3
2	Setup cutting tools on the machines	Sharp cutting tools	Hand injury	2	3	6	2	3	6
3	Setup the raw materials on the machine	Walked on the slippery floor on the machines	Slip and fall	2	2	4	2	2	4
4	Pick up raw materials using electric pallet jack	Unable to stop immediately due to heavy raw materials	Struck	1	2	2	1	2	2
5	Check the cutting tools for every program	Expose to the hot surface during checking the tools	Skin burn	1	1	1	1	1	1

The effectiveness of risk control was evaluated using Relative Risk (RR) and Relative Risk Reduction (RRR) as practised by previous research [20]. RR is a proportional measure that estimates the impact of control measures compared to the baseline risk. An RR value of 1 indicates no effect of the intervention, values below 1 suggest that the control is effective, while values above 1 imply that the intervention is ineffective and may even increase risk [21]. RR is calculated as the ratio of post-control risk (CP) to pre-control risk (PP). In this case, the RR value is 0.25 with CP of 3 and PP of 12.

In addition, RRR was applied to determine the proportional reduction of risk achieved by the intervention relative to the baseline group, using the formula RRR = 1 – RR [22]. Risk control strategies were prioritised for the most prevalent hazards and the most affected risk groups, forming the basis for program recommendations. The RRR for the evaluated case study is 0.75. The results showed that the design of the new storage rack increases the height to ensure the workers do not bend their bodies to lift the cutting tools. This resulted in a 75% risk reduction on the new storage rack used after the improvement.

3.4 Act phase

In the Act phase, the focus is on maintaining the improvements achieved by replacing the rack with a better design. It is essential to conduct training and awareness sessions to ensure that operators and maintenance personnel are familiar with the proper use and handling of the new rack, thereby maximising its ergonomic benefits. Additionally, a structured feedback loop should be established to allow workers to report any issues or suggest improvements based on their daily experiences with the rack. Continuous monitoring is also critical; this can be implemented through periodic ergonomic assessments and safety inspections to verify the long-term effectiveness of the intervention and to ensure that the risk of musculoskeletal strain remains minimised. These administrative processes and procedures are crucial to ensure that the engineering control functions correctly. The effectiveness of the engineering control is, in fact, reliant on humans properly implementing these administrative processes [23].

4.0 CONCLUSION AND RECOMMENDATIONS

In conclusion, utilising the PDCA (Plan-Do-Check-Act) framework for continuous improvement provides a systematic approach in identifying and resolving problems. Based on the assessment of the work task, several outcomes can be concluded.

For the Plan Phase:

- The machining area, particularly the milling operation, posed the highest risk of musculoskeletal disorders (MSD) to workers.
- The Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method identified back injury as the most significant hazard in the machining department, with a risk score of 12.
- The Ishikawa diagram revealed that the main root cause of this issue is the non-ergonomic design of the storage rack, which necessitates that the workers bend their bodies while lifting cutting tools.
- The Rapid Entire Body Assessment (REBA) indicated that the initial work setup design resulted in a score of 9.

For the Do Phase:

- Substitution and engineering controls were implemented by proposing three new storage rack designs. The most effective design was selected using the Pugh Chart, with ergonomics being the main criterion for selection.

For the Check Phase:

- A risk re-evaluation was conducted, showing that the REBA risk score decreased from 9 to 2.
- The risk score assessment was also re-evaluated, resulting in a score of 2, which equates to a 75% Relative Risk Reduction (RRR).

Based on this assessment, the new storage rack is expected to provide long-term benefits to the company. However, ongoing training and awareness sessions are recommended to ensure that operators and maintenance personnel are familiar with the proper use and handling of the new rack. This will maximise its ergonomic benefits and further minimise risks related to human factors and work methods.

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AUTHORS CONTRIBUTION

The authors confirm their contribution to the paper as follows: **study conception and design**: M.D. Abdullah, A.A. Ahmad; **data collection**: M.D. Abdullah; **analysis and interpretation of results**: M.D. Abdullah, A.A.

Ahmad, S.M.B. Abdul Rahman; **draft manuscript preparation**: M.D. Abdullah, A.A. Ahmad, S.M.B. Abdul Rahman. All authors reviewed the results and approved the final version of the manuscript.

DECLARATION OF COMPETING OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

[1] Venkata Subbiah, Krishanna Moorthy, and Rahim Basha, "Measuring the Effectiveness of Health and Safety Practices at Work Place," *International Journal of Research and Analytical Reviews*, vol. 5, no. 4, pp. 852–857, 2018.

[2] Lay Zhan Yek and Mohd Nasrull Abdol Rahman, "A Case Study of An Ergonomic Risk Assessment for Working Posture among Maintenance Workers," *Research Progress in Mechanical and Manufacturing Engineering*, vol. 4, no. 1, pp. 105–114, 2023.

[3] O. B. Demir and F. T. Yilmaz, "The Effect of Posture Regulation Training on Musculoskeletal Disorders, Fatigue Level and Job Performance in Intensive Care Nurses," *BMC Nurs*, vol. 23, no. 1, p. 778, Oct. 2024, doi: 10.1186/s12912-024-02387-w.

[4] F. Yang *et al.*, "The Prevalence and Risk Factors of Work Related Musculoskeletal Disorders among Electronics Manufacturing Workers: A Cross-Sectional Analytical Study in China," *BMC Public Health*, vol. 23, no. 1, p. 10, Jan. 2023, doi: 10.1186/s12889-022-14952-6.

[5] Noorul Huda Zakaria, Norudin Mansor, and Zalinawati Abdullah, "Workplace Accident in Malaysia: Most Common Causes and Solutions," *Business and Management Review*, vol. 2, no. 5, pp. 75–88, 2012.

[6] Dr. J. A. Jogie, Dr. D. Rampersad, Dr. D. Bharrath-Singh, Dr. S. Joseph, Dr. A. Clarke, and Dr. T. La Rosa, "A Comprehensive Review of the Hierarchy of Controls and Barriers to its Implementation," *International Journal of Preventive Medicine and Health*, vol. 5, no. 3, pp. 32–38, Mar. 2025, doi: 10.54105/ijpmh.C1061.05030325.

[7] Thamer Saeed Balubaid and Abdulrahman Basahel, "Assessing the Occupational Safety and Health Management System based on Plan-Do-Check-Act Approach – A Case Study of the Saudi Cargo Sector," *International Journal of Engineering Research & Technology*, vol. 12, no. 3, pp. 378–383, 2023.

[8] A. M. Kholif, D. S. Abou El Hassan, M. A. Khorshid, E. A. Elsherpieny, and O. A. Olafadehan, "Implementation of Model for Improvement (PDCA-cycle) in Dairy Laboratories," *J Food Saf*, vol. 38, no. 3, Jun. 2018, doi: 10.1111/jfs.12451.

[9] A. Daud *et al.*, "Assessing Ergonomic Risks: REBA Analysis of Food Delivery Riders in Eastern Peninsular Malaysia," *Int J Occup Med Environ Health*, vol. 38, no. 2, pp. 170–178, Apr. 2025, doi: 10.13075/ijomeh.1896.02558.

[10] Y. A. A, A. K. A, and I. S. O, "Ergonomic Analysis of Worker Postures in Waste Collection Job," *International Journal of Management and Sustainability*, vol. 6, no. 3, pp. 47–53, 2017, doi: 10.18488/journal.11.2017.63.47.53.

[11] N. Khamarollah *et al.*, "Ergonomic Risk Assessment and Symptoms of Musculoskeletal Disorders among Garment Manufacturing Workers in Kota Bharu, Kelantan," *Industrial Engineering & Management Systems*, vol. 23, no. 1, pp. 63–70, Mar. 2024, doi: 10.7232/iems.2024.23.1.063.

[12] P. Ross, "Ergonomic Hazards in the Workplace," *AAOHN Journal*, vol. 42, no. 4, pp. 171–176, Apr. 1994, doi: 10.1177/216507999404200405.

[13] J.A. Doshi, J.D. Kamdar, S.Y. Jani, and S.J. Chaudhary, "Root Cause Analysis Using Ishikawa Diagram For Reducing Radiator Rejection," *International Journal of Engineering Research and Application*, vol. 2, no. 6, pp. 684–689, 2012.

[14] N. A. Ansari and M. J. Sheikh, "Evaluation of work Posture by RULA and REBA: A Case Study," *IOSR Journal of Mechanical and Civil Engineering*, vol. 11, no. 4, pp. 18–23, 2014.

[15] N. C. Deziel *et al.*, "Applying the Hierarchy of Controls to Oil and Gas Development," *Environmental Research Letters*, vol. 17, no. 7, p. 071003, Jul. 2022, doi: 10.1088/1748-9326/ac7967.

[16] A. A. Rahim, S. N. Musa, S. Ramesh, and M. K. Lim, "A Systematic Review on Material Selection Methods," *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, vol. 234, no. 7, pp. 1032–1059, Jul. 2020, doi: 10.1177/1464420720916765.

[17] Baba Md Deros, Nor Kamaliana Khamis, Ahmad Rasdan Ismail, Haris Jamaluddin, Azmi Mat Adam, and Sarudin Rosli, "An Ergonomics Study on Assembly Line Workstation Design," *Am J Appl Sci*, vol. 8, no. 11, pp. 1195–1201, 2011.

[18] N. J. Izyati, I. S. A., N. A. A., R. A. H., D. A. I., and A. R. D., "Risk Management and Safety Education in Custom Garage," *Journal of Safety Education*, vol. 1, no. 1, pp. 13–18, Jun. 2023, doi: 10.15294/jse.v1i1.70315.

[19] E. Garosi, F. Sheikh, and M. Goodarzi, "Ergonomic Interventions in Risk Reduction," 2025. doi: 10.5772/intechopen.1008463.

[20] G. Pramuhadi, S. Herodian, and F. Anhar, "Kajian Analisis Risiko Keselamatan Kerja di Workshop Traktor," *Jurnal Agricultural Biosystem Engineering*, vol. 4, no. 2, pp. 190–210, Jun. 2025, doi: 10.23960/jabe.v4i2.11104.

[21] Les. Irwig, Judy. Irwig, Lyndal. Trevena, Melissa. Sweet, and Ron. Tandberg, "Relative Risk, Relative and Absolute Risk Reduction, Number Needed to Treat and Confidence Intervals," in *Smart Health Choices: Making Sense of Health Advice*, Hammersmith Books Limited, 2013, ch. 18, p. 358.

[22] A. Barratt, "Tips for Learners of Evidence-based Medicine: 1. Relative Risk Reduction, Absolute Risk Reduction and Number Needed to Treat," *Can Med Assoc J*, vol. 171, no. 4, pp. 353–358, Aug. 2004, doi: 10.1503/cmaj.1021197.

[23] P. Wilkinson and C. MacKenzie, "Effective Engineering Controls ... and the Humans They Depend on," *ACS Chemical Health & Safety*, vol. 30, no. 1, pp. 1–2, Jan. 2023, doi: 10.1021/acs.chas.2c00086.