ERGONOMIC RISK ASSESSMENT AND SAFETY ENHANCEMENTS TOWARD SUSTAINABLE RICE MILLING OPERATION

Jazel Monterola, John Mark Uminga, Jenel Ituriaga
College of Engineering
Occidental Mindoro State College
gadoedmar@gmail.com

ABSTRACT

This study investigates the physical, cognitive, and environmental demands in the rice milling industry in Occidental Mindoro. The assessment involved a sample of 30 employees across various roles, including classifiers, dispatchers, baggers, bran porters, porters, and machine operators. The study incorporated an integration of ergonomic tools, including the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), Ovako Working-Posture Analysis System (OWAS), Rapid Entire Body Assessment (REBA), and NIOSH Lifting Equation for physical-based analysis. CarMenQ and the NASA-TLX, to assess the workload and cognitive strain. The results indicated that bran porters and porters are often exposed to risks of MSDs due to the nature of work. On the other hand, baggers, dispatchers, and rice mill machine operators experienced the highest levels of cognitive workload. Findings also indicated that musculoskeletal disorders (MSDs) are significant contributors to absenteeism, with 86.76% of workers reporting such conditions. Environmental factors, such as excessive noise and humidity, have a further impact on the challenges faced by workers in the bagging and operating areas. The study focused on the implementation of systematic job rotation and the redesign of job descriptions, and recommended ergonomic measures to improve the workplace environment, with the aim to reduce the absenteeism of employees and enhanced the overall worker well-being and operational efficiency in the rice milling sector.

Keywords*: health, ergonomics, occupational safety, rice milling industry, workers' efficiency and productivity*

SDG: *SDG 3*: *Good health and well-being, SDG 8: Decent work and economic growth*

INTRODUCTION

Rice production is an essential part of food security in Asia, as it has served as a staple food over the last 7,000 years for more than 3.5 billion people in agricultural countries, including the Philippines (Amanullah & Shah Fahad, 2017). Mindoro leads the MIMAROPA region in rice production, contributing 6% of the Philippines' total rice output, with the municipality of San Jose as the top producer (Philippine Rice Research Institute - Data Analytics Center, 2023).

However, despite its crucial role, the rice milling industry often disregards ergonomics and worker safety. Rice mill workers face heavy manual material handling tasks such as lifting, pulling, and carrying loads, increasing their risk of back pain, fractures, and fatigue (Astuti et al., 2017), which is referred to as musculoskeletal disorders (MSDs) (Ojukwu et al., 2017), which significantly impacts workers mobility, well-being, and workforce productivity (World Health Organization, 2022). Moreover, workers in rice mill industries are also facing cognitive and environmental risks. As manufacturing becomes more complex due to technology and innovation, the mental challenges correspond with high mental workloads, leading to tiredness, lack of focus, and increased errors (Reiman et al., 2021). Rice milling operations can be especially hazardous, with noise levels during steaming reaching as high as 88.5 dBA, resulting in hearing impairment and cognitive fatigue (Occupational Safety and Health Administration, 2002).

Ergonomics prevents workplace injuries and improves the overall productivity of workers by minimizing physical, cognitive, and environmental stressors (Mehta, 2016). Physical ergonomics deals with posture, muscle strain, and work-related MSDs (Mehta, 2016). Cognitive ergonomics studies the mental workload, stress, and decision-making processes, and it designs systems to aid in the optimization of human task performance while reducing strain from cognitive factors (Shiddiqy et al., 2023). However, environmental ergonomics has demonstrated that environmental factors like light, temperature, and sound affect environmental perception, cognitive performance, and stress (Rezvanizadeh et al., 2023). Ergonomics not only safeguards workers' health and safety but also boosts productivity and reduces the potential costs and waste (Silva et al., 2024).

However, past ergonomics-related studies within the rice milling industry were primarily focused on physical ergonomics, assessing postures, muscle exertion, and musculoskeletal disorders (MSDs) risk (Maulana Rosyidi et al., 2023; Rafiee et al., 2023). However, studies on how cognitive and environmental factors contribute to the workplace stressors experienced by workers are lacking. Thus, this study addresses the gap by integrating physical, cognitive, and environmental ergonomics. This paper intends to provide a more comprehensive ergonomic risk assessment in rice milling operations.

In conclusion, the primary objectives of the study were to identify workers in the rice milling section who are at risk of physical or cognitive strain, or both, and include environmental assessments to recommend strategies for enhancing occupational safety, health, and well-being through the application of various industrial engineering principles and methods.

METHODS

The researchers conducted the study on one of the prominent rice mill corporations located in San Jose, Occidental Mindoro, Philippines. A total of 30 workers in the rice milling facility were involved in the study, including 3 classifiers, 3 dispatchers, 2 forklift operators, 2 baggers, 2 rice mill machine operators, 2 bran porters, and 16 porters. The researchers have conducted a review of related literature, direct observations, surveys, interviews, and actual data gathering to identify occupational risk factors in physical, cognitive, and environmental ergonomics. The CMDQ, OWAS, REBA, and NIOSH Lifting equations are intended for postural and biomechanics-based analysis. On the other hand, CarmenQ and NASA-TLX are utilized to explore and investigate different dimensions of mental workload. Moreover, temperature and humidity indicators, as well as NIOSH sound meter levels, are tools used in the study to assess environmental factors. After identifying the workers who required ergonomic interventions, the researchers proposed targeted solutions aimed at improving working conditions and addressing the challenges faced by the employees. These proposed interventions were presented to the company's stakeholders through a Focus Group Discussion (FGD) to assess their feasibility and alignment with company policies. Upon approval, the ergonomic interventions were implemented over a one-month period to observe their effectiveness and efficiency in improving worker well-being and productivity

Statistical Analysis

Quantitative measures were used to analyze occupational risk factors obtained from the data gathering. This allowed the researchers to create the analysis and derive the relevant implications and conclusions in a non-biased manner. Statistical methods are employed to verify data with a normality test, to identify significant relationships among observed independent and dependent variables with regression analysis, and to reveal workers with high ergonomic risks with a one-way ANOVA Tukey post-hoc test.

RESULTS

Assessments are conducted using various tools to evaluate workers' physical and cognitive demands in the rice milling section of a leading rice milling industry in San Jose, Occidental Mindoro. The study includes a sample of 30 workers who report daily, each performing distinct roles within the corporation.

Physical Ergonomic Assessment

The following analysis includes CMDQ, OWAS, REBA, and NIOSH Lifting Equation. These tools are used to observe how various postures and movements may contribute to the potential risk of developing musculoskeletal disorders.

Table 1 above summarizes factors experienced by rice mill workers gathered from the researchers' survey. Overall, MSDs were widely experienced by the participants, with 86.76 %, while 26.67 % of the workers reported that workload and fatigue brought about by the nature of their work resulted in their absence. The factors were then followed by personal reason (23.33%) and Poor Working Conditions (6.67 %).

Table 1. Summary of Absenteeism Factors Among Rice Mill Workers

ABSENTEEISM FACTORS		
Factor	Percentage	Rank
Musculoskeletal Disorders (MSDs)	86.76 %	1
Poor Working Conditions	6.67 %	4
Workload and Fatigue	26.67 %	2
Personal Reason	23.33 %	3

Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) Result

The results below are based on the researchers' face-to-face survey using a printed questionnaire of the CMDQ distributed to the workers of rice milling areas.

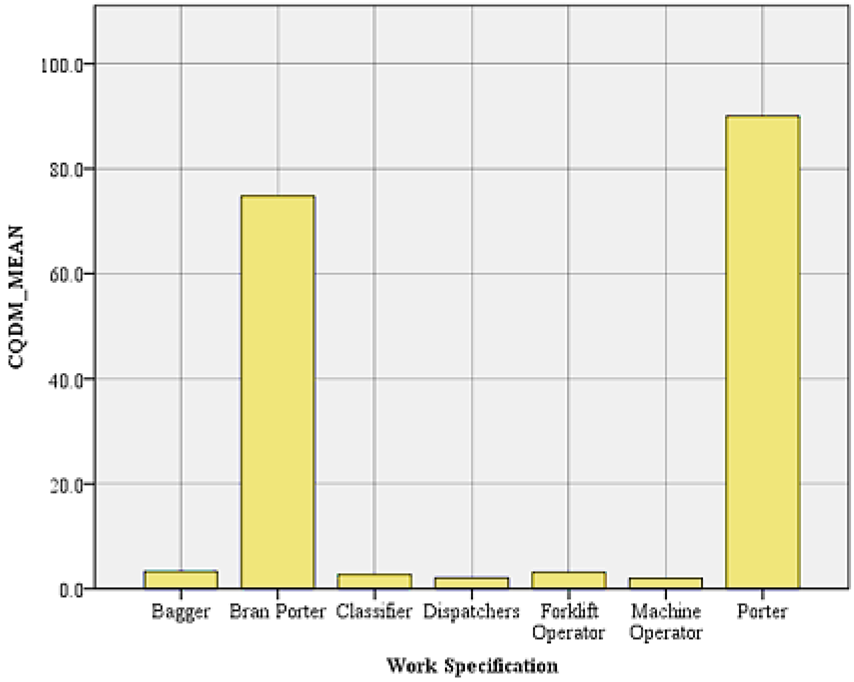

Fig. 1. Summary Report of Discomfort Scores by Work Specification.

According to the researchers' survey, bran porters and porters are the most affected, with a significant number reporting that these workers experience severe discomfort due to the physically intensive nature of their tasks, as shown in Fig. 1

Normality Test

Table 2 demonstrates that all measured physical dimensions follow a normal distribution, indicated by a p-value of less than 0.05. This suggests a 95% confidence level in the results.

Table 2. Normality Test Results

Dimension	Mean	Standard Deviation	p-value	Interpretation
OWAS	2.294	1.051	<0.005	Normal
REBA	8.142	3.386	0.023	Normal
CarMen-Q	2.090	0.388	<0.005	Normal
NASA-TLX	3.289	0.637	<0.005	Normal

Ovako Working-Posture Analysis System (OWAS) Regression Analysis

Table 3 presents the regression analysis of OWAS and REBA. It was identified that in OWAS, workers' sex, height, weight, and work specifications have a positive correlation with their risk levels, with a significant level of less than 0.05. However, REBA validates the OWAS result, except for weight, which was found to be not statistically significant with a p-value of 0.187.

Table 3. Summary of Results in OWAS and REBA.

Independent Variable	Dependent Variable	p-value	Interpretation	Dependent Variable	p-value	Interpretation
Age	OWAS Score	0.375	Not Significant	REBA Score	0.717	Not Significant
Sex	OWAS Score	0.005	Significant	REBA Score	0.000	Significant
Height	OWAS Score	0.013	Significant	REBA Score	0.003	Significant
Weight	OWAS Score	0.034	Significant	REBA Score	0.187	Not Significant
Work Specification	OWAS Score	0.000	Significant	REBA Score	0.000	Significant

One-Way ANOVA – Tukey Post-Hoc Test for OWAS

Table 4 presents the assessment of workers' demographic profiles and OWAS scores. The analysis revealed that the OWAS score does not have a statistically significant impact on age and weight, emphasizing that these factors may not directly affect postural risk levels experienced by workers during the task execution. Moreover, sex, height, and work specifications demonstrate a significant correlation to OWAS score, highlighting that male bran porters and porters with a height of 5'1 to 5'5 ft often experience postural-related risks, due to the various assigned tasks, muscle strength, and anthropometric differences.

Table 4. Workers' demographic profile vs. OWAS score.

Independent	Dependent	Highest Mean	Lowest Mean	Statistical Grouping	Interpretation
Age	OWAS Score	41 to 45 years old	46 to 50 years old	A	Not statistically significant
Sex	Owas Score	Male	Female	A and B	Statistically significant
Height	OWAS Score	5'1 to 5'5 ft	4'6 to 5'0 ft	A and B	Statistically significant
Weight	OWAS Score	51 to 55 kg	36 to 40 kg	A	Not statistically significant
Work Specification	OWAS Score	Bran porters and porters	Machine operators, Baggers, Forklift operators, and Dispatchers	A and B	Statistically significant

Grouping Information Using the Tukey Method and 95% Confidence

OWAS Initial Assessment

Analysis depicts a detailed analysis of various work specifications through OWAS. The interval plot illustrates the average OWAS (Ovako Working Posture Analysis System) scores for various work specifications, along with 95% confidence intervals. According to Fig. 2, the work specifications 6 (bran porters) and 7 (porters) have OWAS mean scores of 3, which suggests that their working postures have harmful effects on the musculoskeletal system, requiring corrective actions as soon as possible. This highlights that Bran Porters and Porters are identified as having the highest ergonomic risks, indicating the urgent interventions to reduce physical strain in these job roles.

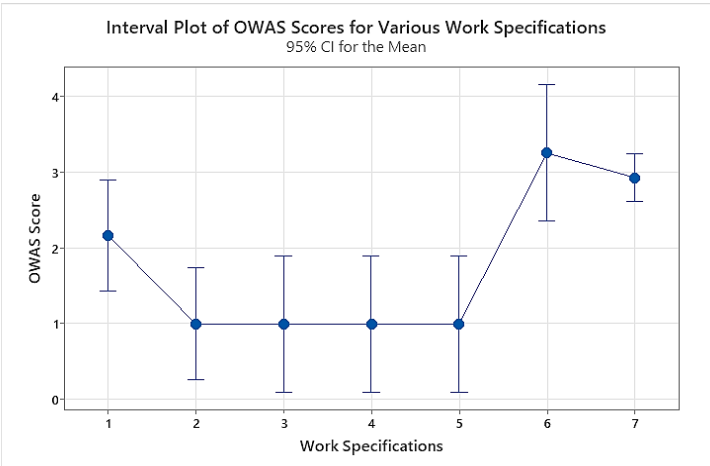

Fig. 2. OWAS Score vs. Work Specifications.

Rapid Entire Body Assessment (REBA)

This study utilized a computer-aided design system (CAD) to define different measurements that are significant for the success of the analysis.

One Way ANOVA – Tukey Post-Hoc Test

Table 5 indicates the Tukey HSD analysis in workers' demographic profiles and REBA score. The assessment identified that the REBA score does not have a significant correlation with age and weight, demonstrating that these are not major factors that lead to the development of musculoskeletal disorders. Furthermore, sex and height are positively correlated to REBA score, emphasizing that male porters and bran porters with a height of 5'6 to 6'0 ft possess higher ergonomic risks, due to the various anthropometric differences and capabilities, the same to OWAS findings.

Table 5. Workers' demographic profiles vs. REBA Score

Independent	Dependent	Highest Mean	Lowest Mean	Statistical Grouping	Interpretation
Age	REBA Score	16 to 20 years old	56 to 60 years old	A	Not statistically significant
Sex	REBA Score	Male	Female	A and B	Statistically significant
Height	REBA Score	5'6 to 6'0 ft	4'6 to 5'0 ft	A and B	Statistically significant
Weight	REBA Score	46 to 50 kg	36 to 40 kg	A	Not statistically significant
Work Specification	REBA Score	Porters and Bran porters	Machine operators and Dispatchers	A, B, and C	Statistically significant

Grouping Information Using the Tukey Method and 95% Confidence

REBA Initial Result

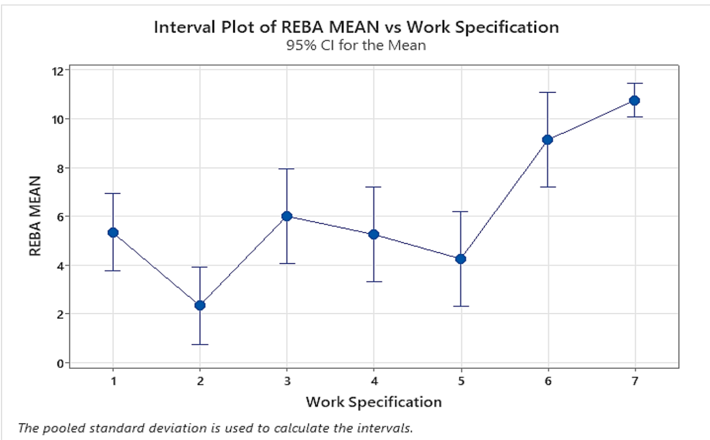

Fig. 3. REBA Initial Result.

The Tukey HSD analysis identifies that male workers with a height range of 5'1" to 6'0" in the work specifications of work specification 7 (porters) and 6 (bran porters) as the primary target for physical ergonomic interventions, with a mean value of 9 and 10, as illustrated in Fig. 3, indicating high risk, investigate and implement change.

NIOSH Lifting Equation

Researchers also evaluated the biomechanics of bran porters and porters through the NIOSH Lifting Equation. Moreover, the researchers utilized lifting index (LI) to identify the level of risk associated with the biomechanics of the workers: ≤1.00 = very low risk, 1.01 – 1.50 = low risk, 1.51 – 2.00 = moderate risk, 2.01 – 3.00 = high risk, and more than 3.00 = very high risk.

The current work movement showed a poor job of lifting posture in both tasks since the actual load is greater than the recommended weight limit, as seen in the result of the NIOSH lifting equation in Table 6

Table 6. Summary of NIOSH scores for Bran porters

Task		HM	VM	AM	DM	CM	FM	RWL	Load	LI
Lifting the sack	Origin	1	0.86	1	0.98	0.9	0.85	14.83 kg	88 lbs	**5.93**
Transporting it into the specified location	Destination	1	0.86	1	0.94	0.9	0.85	14.22 kg	88 lbs	**6.19**
Lifting the sack	Origin	1	0.8	1	0.9	0.9	0.75	11.18kg	88lbs	**7.87**
Transporting it into the specified location	Destination	1	0.95	0.91	0.9	0.9	0.75	12.08kg	88lbs	**7.28**

Legend: HM = Horizontal multiplier factor, VM = Vertical multiplier factor, AM = Asymmetric multiplier factor, DM = Distance multiplier factor, CM = Coupling multiplier factor, RWL = Recommended weight limit, LI = Lifting index.

The current work movement showed a poor job of lifting posture in both tasks since the actual load of the origin (5.93 & 7.87) and destination (LI = 6.19 & 7.28) is greater than the lifting index of 1.01-1.50 (Gi, 2006), as seen in the result of the NIOSH lifting equation in Table 6.

The current lifting posture is risky with LI of greater than 1.00 (Centers for Disease Control and Prevention, 2024). Thus, it was identified that all 16 porters experience high risk with a lifting index value ranging from 5.08 to 20.99, higher than the acceptable threshold

Cognitive Assessment

CarMen-Q using Regression Analysis

Carmen – Q investigates the four mental workload dimensions, such as cognitive, temporal, emotional/health, and performance demand of the workers.

Table 8 presents a summary of the results in CarMen-Q using regression analysis. The table reveals significant correlations between various factors and cognitive workload dimensions, with a p-value of less than 0.05, such as sex, height, weight, and work specification.

Table 8. Summary of Results in CarMen-Q using Regression Analysis.

Independent	Dependent	R - squared	p-value	Interpretation
Sex	Temporal Demand	46.50%	0.000	Significant
Sex	Performance Demand	35.34%	0.001	Significant
Height	Temporal Demand	27.33%	0.013	Significant
Weight	Cognitive Demand	46.61%	0.033	Significant
Weight	Total mental workload	53.38%	0.009	Significant
Work Specification	Cognitive Demand	94.82%	0.000	Significant
Work Specification	Emotional Demand	70.77%	0.000	Significant
Work Specification	Temporal Demand	82.56%	0.000	Significant
Work Specification	Performance Demand	99.03%	0.000	Significant
Work Specification	Total mental workload	93.34%	0.000	Significant

CARMENQ Initial Result using One Way ANOVA – Tukey Post-Hoc Test

Table 9 presents the results of the Tukey HSD test for overall cognitive workload across different work specifications, considering the four dimensions of the Carmen Questionnaire (CQ): cognitive, emotional, temporal, and performance demand. The analysis reveals a statistically significant difference in overall workload demand based on job responsibilities, duties, and the nature of work. The results indicate that baggers and rice mill machine operators experience the highest overall cognitive workload, with mean scores of 2.946 and 2.9304, respectively, placing them in Group A. These values approach a mean score of 3 (often), suggesting frequent exposure to cognitive strain. Followed by dispatchers (B), bran porters (BC), porters (C), forklift operators (CD), and classifiers (D).

Table 9. One Way ANOVA – Tukey Post-Hoc Test of Overall Workload Demand (CQ) vs. Work Specification.

Work Specification	N	Mean	Grouping			
Baggers	2	2.946	A			
Machine Operators	2	2.9304	A			
Dispatchers	3	2.3333		B		
Bran porters	2	2.1643		B	C	
Porters	16	1.9237			C	
Forklift Operators	2	1.871			C	D
Classifiers	3	1.6952				D

Grouping Information Using the Tukey Method and 95% Confidence

National Aeronautics Space Administration Task Load Index (NASA-TLX)

Workers with different work classifications are asked to assign a weight to each sub-scale from their perspective, which is informed by their job specification. This study used Likert-type scales with numerical values such as (1 = low (0 – 9), 2 = medium (10 – 29), 3 = somewhat high (30 – 49), 4 = high (50 – 79), and 5 = very high (80 – 100)) to measure the cognitive demand of the workers.

NASA-TLX using Regression Analysis

Table 10. Summary of Results in NASA-TLX.

Independent Variable	Dependent Variable	R-squared	p-value
Age	Physical Demand	53.99%	0.009
Height	NASA TLX Score	32.27%	0.005
Height	Mental Demand	21.25%	0.040
Height	Temporal Demand	21.87%	0.036
Height	Effort Demand	39.38%	0.001
Height	Frustration Level	23.34%	0.028
Work Specification	NASA TLX Score	83.30%	0.000
Work Specification	Mental Demand	41.63%	0.037
Work Specification	Physical Demand	85.06%	0.000
Work Specification	Temporal Demand	84.56%	0.000
Work Specification	Effort Demand	85.18%	0.000
Work Specification	Frustration Level	74.90%	0.000
Work Specification	Performance Level	44.44%	0.024

Regression analysis in Table 10 identifies a causal correlation of the observed variables. It was revealed through analysis that age, height, and work specification have a positive correlation with NASA-TLX dimensions and score, with a p-value of less than 0.05.

NASA-TLX using One Way ANOVA – Tukey Post-Hoc Test

Table 11 presents the results of a One-Way ANOVA with a Tukey post-hoc test, analyzing NASA-TLX scores across different work roles. The findings reveal significant differences in overall workload perception among various roles. Dispatchers and machine operators exhibit the highest NASA-TLX scores, with mean values of 4.556 (very high) and 4.333 (high), respectively, placing them in statistical Group A. Forklift operators, porters, classifiers, bran porters, and baggers fall into statistical Group B, with mean scores ranging from 3.333 to 2.500, which is categorized in more manageable workload demand. Overall, the results highlight the necessity of targeted ergonomic improvements for dispatchers and machine operators to enhance worker well-being and overall efficiency

Table 11. One-way ANOVA: NASA-TLX Scores versus Work Specification.

Work Specification	N	Mean	Grouping	
Dispatchers	3	4.556	A	
Machine operators	2	4.333	A	
Forklift operators	2	3.333		B
Porters	16	3.1771		B
Classifiers	3	2.778		B
Bran porters	2	2.750		B
Baggers	2	2.500		B

Grouping Information Using the Tukey Method and 95% Confidence

Assessment of Work Environment Design of Rice Mills

To evaluate the physical environment of the rice mill, the researchers initially measured the noise level, humidity level, and temperature.

Table 12 shows the 30 daily measurements of some work environment factors in some rice mill areas to assess noise levels (dBA), humidity (%), and temperature (°C) for morning and afternoon shifts. The data show that the noise level is high in the operating area and bagging area; levels are recorded in the morning at 88.8 and 86.8 dBA and in the afternoon at 89.1, and 87.0 dBA, respectively, which is above the occupational exposure limit recommended by the Occupational Safety and Health Administration (OSHA, 2002) of 85 dBA. This means there may be a risk for long-term hearing damage unless an adequate level of hearing protection is used; thus, noise control measures need to be implemented. Humidity ranges from 53% to 64% and increases during the afternoon in the bran (64%) and dispatch (62%) areas. Humidity is also an important factor for thermal comfort and can lead to heat stress when coupled with increased temperatures (Moradpour et al., 2024). Temperatures were recorded between 32.1°C and 34.2°C, with high values recorded in the afternoon (34.2°C in the operating area and 34.0°C in the bran area). These temperatures exceed the ideal comfort zone for workers, which is 19 to 26°C (Gumasing & Lustañas, 2021).

Table 12. Measurement of Work Environment.

PHYSICAL ENVIRONMENT FACTORS							
Physical Factor	Time	Loading/ Unloading Area	Dragger Area	Bagging Area	Operating Area	Bran Area	Dispatch Area
Noise level (dbA)	Morning	71.0	74.0	86.8	88.8	79.2	71.1
	Afternoon	72.5	75.5	87.0	89.1	80.2	72.3
Humidity (%)	Morning	57	54	55	53	56	56
	Afternoon	60	58	59	57	64	64
Temperature (°C)	Morning	32.7	32.5	32.1	32.7	32.7	32.4
	Afternoon	34.0	33.8	33.5	34.2	34.0	33.5

The study focused on assessing the ergonomic risk experienced by the workers in the rice milling industry. Based on the analysis, One-way ANOVA Tukey Post-hoc Test identified that bran porters and porters are prone to musculoskeletal disorders due to manual material handling and repetitive tasks. Dispatchers, baggers, and rice mill machine operators were determined to be usually facing cognitive challenges from multitasking, operating complex machinery, and maintaining focus in a fast-paced environment.

With a basis in ergonomic principles, the researchers presented proposed interventions to the company's stakeholders through a focus group discussion. The Focus Group Discussion (FGD) was conducted to verify and assess the feasibility of the proposed interventions. Following the discussion and necessary adjustments to the company's rules and regulations, the finalized interventions were approved and discussed below

Physical Ergonomic Intervention

Bran porters are the workers responsible for handling and lifting sacks of bran in the Bran area, a byproduct of rice milling. Their tasks include loading sacks into weighing scales, sewing, and stacking them onto pallets for storage. Rotating workers across tasks requiring varying levels of physical demand can mitigate work-related MSDs and improve their overall productivity (Shiddiqy et al., 2023).

Proposed Ergonomic Intervention

The researchers proposed job rotation to mitigate the development of MSDs among the bran porters and the porters.

Table 13 presents an 8-hour job rotation schedule for two Bran Porters, alternating between lifting sacks to the weighing scale and stacking sacks on pallets every two hours (Padula et al, 2016; The National Institute for Occupational Safety and Health (NIOSH), 2007).

Table 13. Job Rotation Design for Bran Area.

Time Slot	Bran Porter 1	Bran Porter 2
0 – 2 hrs	Lift sacks to the weighing scale	Stack sacks on pallets
2 – 4 hrs	Stack sacks on pallets	Lift sacks to the weighing scale
4 – 6 hrs	Lift sacks to the weighing scale	Stack sacks on pallets
6 – 8 hrs	Stack sacks on pallets	Lift sacks to the weighing scale

Job Rotation Schedule

Porters in the rice mill facility assigned to dispatch, bagging, and dragger areas lift sacks of rice or palay onto delivery trucks, customer vehicles, stacking pallets, and/or designated locations. Porters are located in four different work areas with corresponding numbers of porters assigned, such as storage (6), dragger (6), dispatch (2), and bagging (2), with a total of 16 porters in the entire facility of the rice mill.

Table 14 shows that the job rotation plan has been created to mitigate worker fatigue, prevent injuries, and promote equitable workload distribution among the 16 porters (P) at the rice mill. During their shifts, these porters are responsible for handling heavy sacks of rice, weighing between 5 kg and 50 kg. To address this, a system will be implemented where porters rotate between various tasks every 2 hours. By rotating tasks, porters experience less fatigue, fewer injuries, and improved efficiency. Thus, this system benefits workers' well-being and milling operations by ensuring a fair and effective work environment

Table 14. Job Rotation Schedule.

Time slot	Storage Porters (6)	Dragger Porters (6)	Dispatch Porters (2)	Bagging Porters (2)
0 – 2 hrs	P3, P4, P5, P6, P13, P14	P7, P8, P11, P12, P15, P16	P1, P2	P9, P10
2 – 4 hrs	P7, P8, P9, P10, P15, P16	P1, P2, P5, P6, P13, P14	P3, P4	P11, P12
4 – 6 hrs	P1, P2, P3, P4, P11, P12	P7, P8, P9, P10, P15, P16	P5, P6	P13, P14
6 – 8 hrs	P5, P6, P9, P10, P13, P14	P1, P2, P3, P4, P11, P12	P7, P8	P15, P16

Cognitive Ergonomic Intervention

At the research site, there are three female dispatchers responsible for managing the distribution and inventory of rice sacks based on customer orders.

Proposed Ergonomic Intervention

Since different dispatcher roles involve varying levels of difficulty, job rotation was proposed by the researchers to help balance cognitive stress by alternating between tasks with different cognitive and physical demands, reducing fatigue and improving overall performance. A study conducted by (Mlekus & Maier, 2021), a job rotation schedule with an interval of 2 hours. This interval was a consensus between studies (de Oliveira Sato & Cote Gil

Coury, 2009), and is compatible with the premise of lactic acid reduction, which is connected to the muscle soreness and fatigue due to intensive workload demand.

During the Focus Group Discussion (FGD), stakeholders emphasized that frequent task *bala*, as shown in Table 15.

Table 15. Proposed Job Rotation Schedule.

Time	Small Scale Dispatcher	Large Scale Dispatcher	Inventory Management Dispatcher
Day 1	D1	D2	D3
Day 2	D3	D1	D2
Day 3	D2	D3	D1
Day 4	D1	D2	D3

Proposed Ergonomic Intervention

At the research site, two baggers operate tank machines for daily operations—one handling 5 kg portions and the other managing 25 kg portions.

As shown in Table 16, baggers will begin their shift in their original work positions and rotate every two hours, resulting in four rotations within an eight-hour work period, according to the recommendations of the Occupational Safety and Health Organization.

Table 16. Proposed Job Rotation Schedule

Time	5kg Bagger	25kg Bagger
0 – 2 hrs	B1	B2
2 – 4 hrs	B2	B1
4 – 6 hrs	B1	B2
6 – 8 hrs	B2	B1

Work Specification Definition

At the research site, operators are classified into two roles: the head machine operator and the assistant operator. The head operator is typically stationed on the 2nd floor of the rice milling facility, where the main control system for all machines is located. Their primary responsibility is to oversee and regulate the entire milling process from a central control point. Meanwhile, the assistant operator is positioned on the 1st floor to provide support and ensure smooth execution of the milling process by handling tasks that require on-site adjustments and maintenance.

Proposed Ergonomic Intervention

Job Description Design

The current division of duties between the head operator and the assistant operator reflects a significant imbalance in the distribution of responsibilities, leading to an uneven workload. While both the head and assistant operator are capable of performing basic tasks, certain key responsibilities are designated solely for the head operator. These include calculating batch milling and evaluating worker performance according to company regulations.

Table 17. Proposed job description

Head Operator	Assistant Operator
Operating machines and managing the system in the control room (1st and 2nd floor).	Substitute the head operator to operate all operations if not available.
Starting the machines and configuring measurement settings on the 2nd floor	Starting the machines and configuring measurement settings on the 1st floor
Monitoring production flow to ensure efficiency on the 2nd floor.	Monitoring machines' operation effectiveness to ensure efficiency on the 1st floor
Monitoring machines' operation effectiveness to ensure efficiency on the 2nd floor	Monitoring production flow to ensure efficiency on the 1st floor.
Inspecting product quality to maintain standards (2nd floor).	Inspecting product quality to maintain standards (1st floor).
Cleaning the rice milling area on the 2nd floor	Cleaning the rice milling area on the 1st floor
Calculating the batch milling.	Help the forklift operators in organizing the products
Evaluating workers' performance under the supervision of the head operator.	Collecting product samples for assessment and analysis.

To address this imbalance and reduce cognitive stress and strain on both operators, the researchers have proposed a revised job description that aims to reallocate duties and responsibilities systematically. The proposed job description is presented in Table 17.

The management approved and implemented a one-month intervention for the identified workers who needed ergonomic intervention. The implementation duration was supported by existing ergonomic-related studies. After one month of monitoring and implementation, the researchers conducted a post-test survey using CMDQ for physical assessment, and CarmenQ and NASA-TLX for cognitive assessment to evaluate the impact of the proposed intervention. The researchers utilized a statistical tool called the two-sample t-test to determine whether there is a significant difference between the current work setup and after the ergonomic intervention. The evaluation is presented below.

Intervention Assessment

Physical Intervention – Bran Porters and Porters

Table 18 presents the t-test result demonstrates that the observed difference is statistically significant, as it satisfies the significance threshold ($p<0.05$). These values provide strong evidence to reject the null hypothesis, confirming that the researchers' proposed intervention was effective in significantly reducing the risk of musculoskeletal disorders

Table 18. Paired Sample Test.

	Mean	Std. Deviation	Std. Error Mean	T-value	Degrees of Freedom (n – 1)	P-value (2-paired)
CMDQ Mean Pre-test and Post-test	44.91	4.54	1.07	41.96	17	0.000

Intervention Assessment

Carmen Questionnaire – Dispatchers and Rice Mill Machine Operators

Table 19 reveal that a systematic job rotation for dispatchers and job description for rice mill machine operators has a positive effect on lowering the cognitive risk experienced by the dispatchers and rice mill machine operators, with a t-test value of 12.33 (p-value = 000), that confirms this variability is highly significant ($p<0.05$), which provides strong evidence to reject the null hypothesis. The result suggests that the intervention effectively reduced the cognitive demands placed on workers, potentially leading to improved productivity, decision-making capabilities, and overall job satisfaction.

Table 19. Paired Sample Test

	Mean	Std. Deviation	Std. Error Mean	T-value	Degrees of Freedom (n – 1)	P-value (2-paired)
CarmenQ Mean Pre-test and Post-test	0.65	0.12	0.05	12.33	4	0.000

NASA – TLX – Baggers and Rice Mill Machine Operators

Table 20. Paired Sample Test.

	Mean	Std. Deviation	Std. Error Mean	T-value	Degrees of Freedom (n – 1)	P-value (2-paired)
NASA – TLX Mean Pre-test and Post-test	1.04	0.83	0.04	25.0	3	0.000

Table 20 analysis indicates that systematic job rotation and clearly defined job descriptions are positively correlated with a reduction in mental workload, with t-test results (t = 25.0, p = 0.000) validating the statistical significance of this reduction (p < 0.05). These findings demonstrate that the intervention effectively reduces cognitive strain across six workload dimensions, contributing to potential improvements in efficiency, accuracy, and overall worker well-being

Productivity Ratio

The productivity ratio is illustrated through the employees' absenteeism, which reflects the operational efficiency of the workforce. The initial and final absenteeism rates observed during a 30-day measurement are depicted below.

As indicated in Table 21, absenteeism rates dropped from 25% to 67% after the intervention proposed by the researchers, indicating that productivity has also improved proportionally. Since low absenteeism indicates enhanced worker efficiency, improved job satisfaction, and equal workload distribution among the workforce due to workplace interventions such as job rotation.

Table 21. Initial and final productivity ratio.

Area	No. of workers	Total monthly workdays	Initial absent days	Absenteeism ratio (initial)	Final absent days	Absenteeism ratio (final)	Improvement percentage
Porters	16	416	39	9.38%	22	5.29%	43.59%
Bran porters	2	52	6	11.54%	2	3.85%	66.67%
Bagging area	2	52	4	7.69%	3	5.77%	25.00%
Operating area	2	52	5	9.62%	2	3.85%	60.00%
Dispatch area	3	78	8	10.26%	5	6.41%	37.50%

DISCUSSION

Based on multiple ergonomic assessment tools, evaluations were conducted to examine the physical, cognitive, and environmental ergonomics of work conditions among workers in the rice milling industry. The results revealed that workers such as porters and bran porters are in need of physical ergonomic interventions, while baggers, dispatchers, and rice mill machine operators require cognitive ergonomic support. In response to these findings, the researchers proposed a set of ergonomic interventions, which were further refined and validated through a Focus Group Discussion (FGD) with the company's stakeholders to ensure feasibility within the context of company policies and operational constraints. Following the company's stakeholders' feedback and necessary revisions, the proposed interventions were finalized and approved.

To mitigate the risk of musculoskeletal disorders among porters and bran porters, the implementation of job rotation was recommended. Supported by ergonomic literature and guidelines from the Occupational Safety and Health Administration (OSHA), it is recommended that job rotation occur every two hours to promote equitable physical workload distribution and reduce muscle fatigue associated with lactic acid buildup. Recognizing its benefit, the researchers also recommended a two-hour job rotation for dispatchers and baggers to address both physical and cognitive workload demands. However, company stakeholders raised operational concerns regarding the frequent rotation of dispatchers, emphasizing that shifting tasks every two hours could result in confusion and increased errors due to the continuous flow of customers. As a compromise, stakeholders proposed a daily rotation for dispatchers, rather than every two hours, balancing ergonomic benefits with operational efficiency. Additionally, to address the cognitive strain and uneven distribution of responsibilities among rice mill machine operators, the researchers proposed a revised job description that divides the roles of the head and assistant operators. While both are capable of performing basic operational tasks, specific key responsibilities such as batch milling calculations and performance evaluations remain designated to the head operator, by company protocols. This intervention aims to foster a more balanced cognitive workload and improve task clarity.

To evaluate the effectiveness of the ergonomic intervention, the researchers employed a two-sample t-test to determine whether there was a statistically significant difference in the levels of physical and cognitive strain experienced by workers before and after the intervention. This analysis was based on pre-test and post-test surveys conducted over a one-month implementation and observation period, using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), the Cognitive and Mental Workload Questionnaire (CarMen-Q), and the NASA Task Load Index (NASA-TLX). The results revealed that the ergonomic interventions, such as the implementation of systematic job rotations and the revision of job descriptions, had a significant positive impact on worker well-being and productivity. The statistical analysis yielded a p-value less than the conventional significance threshold ($p < 0.05$), indicating that the interventions effectively improved workplace conditions and reduced the physical and cognitive strain experienced by workers.

To further validate the effectiveness and efficiency of the interventions, the researchers assessed worker productivity through absenteeism rates. Following the implementation of the proposed ergonomic strategies, the absenteeism ratio dropped significantly, from 25% to 67%. This substantial decrease suggests improved productivity, job satisfaction, and more equitable workload distribution among workers.

CONCLUSION

The study identified that implementing systematic job rotation every two hours significantly reduced the risk of MSDs, with t-test results confirming a statistically significant improvement ($p < 0.05$) in musculoskeletal discomfort. Furthermore, the introduction of systematic job rotation and defined job descriptions effectively lowered mental workload for these workers, as confirmed by the t-test. These work practices also result in boosting workers' productivity, and lessen the cases of absenteeism with an improvement percentage ranging from 25 to 66.67%. In addition, excessive heat (34.0°C), humidity (64%), and noise levels (89.1 dBA) exceeded recommended occupational safety limits, affecting worker well-being.

Proactive measures–such as ventilation improvements, noise control strategies, and appropriate protective equipment–are necessary to create a safer and more productive working environment.

The researchers recommended that rice milling management implement job rotation strategies to reduce the risk of musculoskeletal disorders (MSDs) among workers. Additionally, increasing the number of workers assigned to these high-risk areas can further reduce individual lifting frequency and associated strain. To address poor lifting postures observed, companies should consider investing in adjustable pallets. These would enable lifting at waist level, encouraging a neutral spine position and reducing the risk of lower back injuries. Moreover, the use of hearing protection should be mandated in areas with high noise exposure, particularly the bagging and operating sections, in line with OSHA standards, to prevent long-term hearing damage. It is also strongly recommended that future researchers include the assessment of air quality monitoring devices to measure dust particles within the facility. Maintaining acceptable dust levels not only enhances workplace safety but also supports product quality and compliance with occupational health regulations.

ACKNOWLEDGMENT

The authors sincerely express their gratitude to everyone who contributed significantly to the successful completion of this research.

REFERENCES

Amanullah, & Shah Fahad. (2017). Rice - Technology and Production. *In InTech eBooks*. https://doi.org/10.5772/64480

Astuti, R. D., Susmartini, S., & Kinanthi, A. P. (2017). Improving the work position of worker based on manual material handling in rice mill industry. *AIP Conference Proceedings*, *1902*, 020043. https://doi.org/10.1063/1.5010660

Centers for Disease Control and Prevention. (2024). Revised NIOSH Lifting Equation. Ergonomics and Musculoskeletal Disorders. *Centers for Disease Control and Prevention.* https://www.cdc.gov/niosh/ergonomics/about/RNLE.html

de Oliveira Sato, T., & Cote Gil Coury, H. J. (2009). Evaluation of musculoskeletal health outcomes in the context of job rotation and multifunctional jobs. *Applied Ergonomics*, *40*(4), 707–712. https://doi.org/10.1016/j.apergo.2008.06.005

Maulana Rosyidi, Auditya Purwandini Sutarto, & Nailul Izzah. (2023). Addressing Ergonomics in Paddy Milling: Insights from RULA, Nordic Body Map, and Anthropometry. *Qomaruna*, *1*(1), 1–14. https://doi.org/10.62048/qjms.v1i1.21

Mehta, R. K. (2016). Integrating Physical and Cognitive Ergonomics. *IIE Transactions on Occupational Ergonomics and Human Factors*, 4(2-3), 83–87. https://doi.org/10.1080/21577323.2016.1207475

Mlekus, L., & Maier, G. W. (2021). More Hype Than Substance? A Meta-Analysis on Job and Task

Rotation. *Frontiers in Psychology*, *12*(12). https://doi.org/10.3389/fpsyg.2021.633530

Moradpour, Z., Jafari, M. J., Dehghan, S. F., Jalali, M., & Hesam, G. (2024). Heat stress, thermal comfort and control strategy in a warm-humid workplace. International Journal of Biometeorology, 68(12), 2507–2514. https://doi.org/10.1007/s00484-024-02760-z

Occupational Safety and Health Administration. (2002). Temporary Worker Initiative Noise Exposure and Hearing Conservation. *U.S. Department of Labor.* https://www.osha.gov/sites/default/files/publications/OSHA3953.pdf

Ojukwu, C. P., Anyanwu, G. E., Nwabueze, A. C., Anekwu, E. M., & Chukwu, S. C. (2017). Prevalence and associated factors of work related musculoskeletal disorders among commercial milling machine operators in South-Eastern Nigerian markets. *Work*, *58*(4), 473–480. https://doi.org/10.3233/wor-17264

Padula, R. S., Comper, M. L. C., Sparer, E. H., & Dennerlein, J. T. (2016). Job rotation designed to prevent musculoskeletal disorders and control risk in manufacturing industries: A systematic review. *Applied Ergonomics, 58, 386–397.* https://doi.org/10.1016/j.apergo.2016.07.018

Philippine Rice Research Institute - Data Analytics Center. (2023). State of the Rice Sector in Occidental Mindoro. *Philrice.gov.ph.* https://www.philrice.gov.ph/ricelytics/main/province/51

Reiman, A., Kaivo-Oja, J., Parviainen, E., Takala, E., & Lauraeus, T. (2021). Human factors and ergonomics in manufacturing in the industry 4.0 context – A scoping review. *Technology in Society*, *65*, 101572. https://doi.org/10.1016/j.techsoc.2021.101572

Rezvanizadeh, M., Mohammad-Ghasemi, M., Soltanzadeh, A., & Sadeghi-Yarandi, M. (2023). Development of a novel ergonomic index assessment in the workplace based on physical, cognitive, and environmental components. *Work*, *75*(3), 1071–1086. https://doi.org/10.3233/wor-220335

Shiddiqy, I. A., Bisnis, D., & Semarang, J. (2023). Benefits Of Job Rotation: Systematic Literature Review (SLR). *Jurnal Manuhara : Pusat Penelitian Ilmu Manajemen Dan Bisnis*, *2*(1), 144–151. https://doi.org/10.61132/manuhara.v2i1.440

Silva, D. R., De Jesus Laurenço, A., Galvão, J. Q., De Oliveira Lopes, M. E., De Oliveira Barros, Y., Araújo, C. a. P., Da Silva, J. V., Calazans, M. L., Silva, W. S. L., Gomes, E. M., & De Paula, J. S. (2024). Impact of ergonomics on workers' performance and health. *International Journal of Advanced Engineering Research and Science*, *11*(10), 44–58. https://doi.org/10.22161/ijaers.1110.5

The National Institute for Occupational Safety and Health (NIOSH). (2007). Ergonomic guidelines for manual material handling. *Centers for Disease Control and Prevention* . (2007). https://doi.org/10.26616/nioshpub2007131

World Health Organization. (2022). Musculoskeletal health. *World Health Organization: WHO.* https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions