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Work posture risk comparison of RULA and REBA based on measures of assessment-score variability: A case study of the metal coating industry in Thailand

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Abstract

This study examines the work posture risk comparison of RULA and REBA based on measures of assessment-score variability. During the metal coating process, chemicals were frequently employed, necessitating a heightened level of caution among the employees. The Cornell Musculoskeletal Discomfort Questionnaires (CMDQ) revealed the manifestation of physical discomfort among employees. In this study, the rapid upper limb assessment (RULA) and the rapid entire body assessment (REBA) were used to identify ergonomic concerns related to the work of employees in the black oxide coating department of a metal coating firm. The sensitivity of risk assessment between the two methods was investigated, considering the mean and variability of the assessment scores. Consideration was given to the diverse and crucial work positions of employees at each station, focusing exclusively on the standing working posture. In the black oxide coating section, there were 12 steps that 20 workers had to complete. Under the same working postures, the overall average RULA score was determined to be at a high-risk level, whereas the overall average REBA score was at a moderate-risk level. As a result, the RULA method had a greater capacity for risk warning than the REBA method. Levene's test was also applied to determine whether the variances of the risk scores computed using the two techniques were equal. The results of the analysis showed that the variances in the scores using the two methods were not significantly different.

Keywords: Ergonomic risk assessment, Metal coating industry, Musculoskeletal disorders, Occupational health, Rapid entire body assessment, Rapid upper limb assessment, Small-scale metal coating firm, Work posture analysis.

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1. Introduction

The metal industry holds paramount significance in the country's development due to its foundational role in linking with various industries, including automotive, machinery, electrical appliances, infrastructure construction, and real estate. Metal coating is a crucial technique in this industry, where one type of metal is applied to another to enhance surface hardness, wear resistance, and prevent corrosion.This process also improves the workpiece's value and aesthetic appeal [1, 2]. The metal coating process involves the use of several instruments and chemicals, which could have a negative impact on the environment and pose hazards to worker safety [3, 4].Previous research often compared risk assessment tools based on average scores or individual scores without considering the distribution of risk scores. However, significant variance could result in instances where the average score is not high, yet a high-risk score is present, necessitating urgent corrective action. The case study company, a small-scale metal coating manufacturer headquartered in the province of Samut Prakan, Thailand, focused on three production processes: black oxide coating, zinc phosphate coating, and manganese phosphate coating, primarily serving automakers. Despite minimal machinery use, the company heavily relied on manual labor.

Initial observations revealed poor ergonomic working postures and worker discomfort. The primary goal of this study was to assess ergonomic risks among workers in the metal coating process. One more goal of the study was to see how well the rapid upper limb assessment (RULA) and the rapid entire body assessment (REBA) worked at assessing risk in different critical work postures by looking at mean and standard deviation. Statistical tests, including Levene's test, were employed to assess the equality of variances between the RULA and REBA scores. This methodological rigor enhances the credibility of the study's findings and contributes to the scientific discourse on ergonomic assessments.The structure of this research paper began with the statement of the problem, literature review, research methodology, research results, and conclusions.

2. Literature Review

Ergonomics refers to the science of arranging work conditions to suit workers or the study of people in the law of work. It is a science that examines how people engage with their jobs and their working environments to appropriately improve working circumstances. It is to ensure work efficiency, which includes ensuring that employees can support themselves and maintain excellent health [5-7].

Ergonomics, the science of arranging work conditions to suit workers or the study of people in the law of work, is a discipline that delves into how individuals interact with their jobs and working environments. Its aim is to enhance working conditions appropriately, ensuring both work efficiency and the well-being of employees [8].This involves various methods:

1. Utilizing a checklist as a query to assess potential work-related physical discomfort.
2. Employing observational assessments, such as RULA, REBA, the ovako working posture analysis system (OWAS), and rapid office strain assessment (ROSA), to gauge posture and working conditions.
3. Implementing direct measurements through electronic tools like the heart rate monitor and oxygen consumption analyzer to estimate workload and energy expenditure.

The RULA method, developed in 1993 by McAtamney and Corlett [9] serves to evaluate the level of risk or danger posed by an employee's upper body posture and movement. This assessment is divided into two main groups: Group A, which evaluates the upper arms, lower arms, and wrists; and Group B, which assesses the neck, trunk, and legs.

The REBA method is a rapid work posture assessment that evaluates the neck, trunk, legs, arms, and hands. Developed in 2000 by Hignett and McAtamney [10] this method is suitable for assessing various parts of the body in tasks involving rapid posture changes or non-stationary work, including activities with unpredictable work postures, such as service work. The assessment is divided into two groups: Group A, which evaluates the torso, neck, and legs; and Group B, which comprises an assessment of the upper arms, lower arms, and wrists, including an evaluation of object grasping [10, 11].

Work-related musculoskeletal disorders (WMSDs) have gained recognition as some of the most prevalent occupational illnesses in recent years, posing several limitations on everyday activities for affected persons [12]. The work of Choobineh, et al. [13] addressed the negative health impacts of difficult working postures and non-ergonomic workstations on employees, including WMSDs.WMSDs incur significant expenses, encompassing direct costs such as compensation, administrative and medical expenditures, and indirect costs like absenteeism, product quality, and productivity losses [14, 15]. Rahman [16] utilized the RULA approach to analyze and evaluate the work postures of 39 workers in the ceramic industry, determining the appropriateness of each posture. In the manufacturing sector of the ceramic industry, no posture was found to be risk-free for workers. Asghari, et al. [17] conducted a study on musculoskeletal pain among nurses in the operating room at Tabriz University of Medical Sciences (TUMS). The Nordic Musculoskeletal Questionnaire (NMQ) was initially employed to gather information about musculoskeletal pain, revealing the lower back, knees, ankles/feet, and neck as the most frequently affected body parts. The second method involved using the REBA method for work assessment, indicating a consistent high risk of muscle and bone injuries for operating room nurses.

Meksawi, et al. [18] conducted an ergonomic risk assessment focusing on 427 rubber tappers, averaging 38 years old. Using the RULA method for job evaluation, they identified rubber tapping as a hazardous occupation with a risk of musculoskeletal disorders (MSDs). The study suggested that developing suitable assistive equipment for the rubber tapping sector could help alleviate or treat back pain.

Aligning procedures with ergonomic principles is crucial, as it enhances employee satisfaction, comfort, and safety while reducing the risk of accidents, stress, worry, and fatigue. Simultaneously, it enhances the effectiveness of activities [19]. Proactive ergonomics and corrective measures are common techniques for preventing MSDs and enhancing productivity and quality in the automobile sector [20, 21]. Notably, contextual issues, inappropriate intervention tactics, ineffective stakeholder involvement, and inadequate ergonomic analyses can contribute to unsatisfactory intervention practices [22, 23].

Neumann, et al. [21] and Burgess-Limerick [23] demonstrated that a mix of measures, such as information and education, as well as both mandatory and volunteer strategies, might lower demands on the body and MSD risk factors. According to Van Der Molen, et al. [24] the use of lifting tools and other ergonomic engineering controls, along with a participatory strategy and stakeholder participation, would effectively lower long-term physical labor requirements and MSDs. In a recent study, Kittipanya-Ngam, et al. [25] investigated a paint factory using a case study approach, identifying seven material handling points. A key concern addressed was the movement of materials between the 2nd and 1st floors. The study focused on designing vertical material handling equipment based on the Karakuri Kaizen principle, emphasizing a connection to ergonomic principles.

Domingo, et al. [26] conducted an ergonomic risk evaluation among 101 randomly selected Filipino construction workers using the NMQ. The study revealed that shoveling resulted in the highest pain scores. Subsequently, ergonomic risks were assessed through the RULA and REBA methods. RULA scores indicated that most jobs exhibited issues requiring immediate changes, while the REBA approach highlighted drilling as posing the highest risk. Ijaz, et al. [27] investigated musculoskeletal disorders among workers in Pakistan's brick manufacturing industry, employing multi-stage sampling. The sample included 150 workers, comprising 105 men and 45 women. The RULA evaluation results demonstrated a consistent level 4 risk at every step, indicating a very high risk that requires immediate correction. In the REBA method, the clay-mixing step for brick formation scored 13 points, signifying a very high-risk condition demanding prompt improvement.

Cremasco, et al. [28] evaluated the postures of operators manually feeding a wood chipper in the forestry sector and compared the effectiveness of the RULA and REBA methods in assessing the risk of biomechanical postural strain. The findings revealed upper limb postural issues, highlighting RULA as a more preventive measure to safeguard the operator's health during the specified tasks.Yarandi, et al. [29] evaluated three ergonomic risk assessment tools (the Novel Ergonomic Postural Assessment (NERPA), RULA, and REBA) for screening musculoskeletal disorders among employees in a power plant equipment industry in Iran. Involving 295 participants from six occupational groups, the research identified RULA as the most effective method for predicting the risk of musculoskeletal disorders across diverse tasks, based on correlations between prevalence rates and predicted risk levels.In their study, Kee, et al. [30] investigated maximum holding times (MHTs) across various body postures using three methods: OWAS, RULA, and REBA. Compared to OWAS and REBA, RULA found more stressful postures. It also had a stronger relationship between its overall score and MHTs and other postural load criteria.

Through an extensive literature review, it was observed that ergonomic risk assessment was prevalent across diverse industries, but limited information was available for its application within small-scale metal coating firms. Additionally, while numerous risk assessment tools existed, it was crucial to recognize the widespread use of the RULA and REBA methods. Furthermore, the evaluation of risk assessment tool performance typically relies on average scores, with limited attention given to comparing performance in terms of risk score variability. Consequently, this research included a gap analysis to address these key considerations.

The RULA and REBA methods were regarded as alternative forms of assessment relying on observational assessment, particularly suitable for tasks involving minimal movement. Typically, only one photograph was chosen to serve as a sample for assessing the worst posture or the position that took the most time. The evaluator's experience frequently influenced the decision for an ergonomic risk assessment, which might have led to biases and errors. In this study, a variety of images judged to be important for risk assessment were used. Subsequently, both the mean and standard deviation were calculated and subjected to further analysis.

3. Materials and Methods

The metal coating processes in the case study of the metal industry in Thailand were categorized into the following three kinds: (1) black oxide coating, (2) manganese phosphate coating, and (3) zinc phosphate coating. However, the black oxide coating was chosen for this study because it had the largest number of production orders. A total of 20 employees were involved, and the work process was divided into 12 steps, as follows:

Station 1: Inspection of goods received: Workpieces were received from customers and examined before being sent to the next station. This station had two full-time employees. Equipment for loading and unloading was a cart.

Station 2: Loading: Workpieces were sorted by the type of coating method. Two employees were stationed at this station. Jigs and fixtures were the tools used to hold the workpieces in place.

Station 3:Boiling to clean up oil stains: This process proceeded to clean up oil stains attached to the workpieces. An employee was stationed at this station.

Station 4: Use of hydrochloric acid: Before applying black oxide, the workpiece's surface was etched using hydrochloric acid to keep it clean. An employee was stationed at this station.

Station 5: Hydrochloric acid washing: Hydrochloric acid stains on the workpieces needed to be removed with water. Two employees were stationed at this station.

Station 6: Metal blackening or black oxide: Workpieces were coated with black paint to enhance strength and resistance to wear. There were two employees at this station.

Station 7: Blackening washing: Work pieces were cleaned with water after the blackening process. Two employees were stationed at this stage.

Station 8:Water washing: In this stage, workpieces were also carefully cleaned. An employee was stationed at this point.

Station 9: Drying: After washing, fire and air were applied to dry the workpieces. An employee was stationed at this station.

Station 10: Oil dip: This stage proceeded to prevent rust after blackening.

Station 11: Final inspection: After the coating process, the finished workpieces were examined for flaws.

Station 12: Packing: The finished product was packaged and kept in the warehouse.

The Cornell Musculoskeletal Discomfort Questionnaires (CMDQ) were utilized for conducting interviews with all 20 employees, and the resulting scores are summarized in Table 1.

Table 1.
Summary of CMDQ scores, which indicated employee pain levels.

Organ	Pain level				
	Level1	Level 2	Level 3	Level 4	Level 5
Head and neck	0	0	3	7	10
Shoulder	0	0	6	10	4
Arm	0	1	3	8	8
Central back	0	3	6	5	6
Lower back	0	0	0	5	15
Hip	0	3	10	7	0
Thigh	3	8	3	5	1
Knee	4	7	4	5	0
Leg and foot	0	1	5	8	6

In Table 1, employees reported experiencing pain in various body parts. The lower back emerged as the most frequently cited area, with 15 employees reporting pain at level 5. Following closely were the head and neck, with 10 individuals reporting pain at level 5. These employee surveys were pivotal in identifying work-related hazards, and the research further utilized the RULA and REBA procedures to measure and compare ergonomic risks associated with various postures.

A total of 10–20 pictures were taken at each workstation. Following the brainstorming group session, 4–9 photos depicting the worst working positions were selected for ergonomic risk assessment, considering each form.

The twelve-step black oxide coating procedure was divided into the following two categories:

Group A: Employees worked with a standing posture, as illustrated in Figure 1. Both the RULA and the REBA methods could be employed as assessment tools. In group A, there were nine stations in total, numbered 1, 3 - 10. A maximum of nine photos was chosen for station 4, while six photos were taken per workstation for stations 1, 3, 5, 7, and 9. Additionally, five photos were taken per workstation for stations 6, 8, and 10.

Group B: Employees worked with a sitting posture. Group B comprised a total of three workstations: stations 2, 11, and 12. Working in Group B with a sitting position was not considered in this study because the REBA method could not be applied.

A total of 54 photos from the black oxide coating process were selected for risk assessment. Two techniques, RULA and REBA, were used to determine the risk of each photo, resulting in a total of 108 posture assessments. The working posture analysis was exemplified in the first image on the left in Figure 1c), Station 4. To show the body angles, the analysis of the working posture of such images could be shown in Figure 2.

4. Results

At each workstation, various improper working postures were selected for this research. The assessment of each photo is detailed in Table 2.

The descriptive statistics of the RULA scores and REBA scores for each station, such as the average and the standard deviation, could be calculated as shown in Table 3. The box-and-whisker plots in Figure 3 illustrate the numerical data groupings of localization, spread, and skewness.

The overall averages for the RULA and REBA scores were 6.3148 and 4.4259, respectively, with 95% confidence intervals of 6.0671 to 6.5625 and 4.1474 to 4.7045, respectively.

The overall average of the RULA score was 6.3148, approaching a full 7 points. According to McAtamney and Corlett [9] this score level indicated a need for attention and urgent work improvement. In contrast, the overall average of the REBA score was 4.4259. The REBA score could potentially go as high as 12 points. As a result, less than half of the total score was attributable to the risk determined using the REBA method. According to Hignett and McAtamney [10] the overall average of the REBA score was deemed to represent a medium risk, suggesting the need for additional research and development.

a) Station 1

b) Station 3

c) Station 4

d) Station 5

e) Station 6

Figure 1.
Examples of standing work postures in group A.
Note: Stations 2, 11, and 12, where employees sat and worked, were excluded from the study as the REBA method was inapplicable.

Figure 2.
An example of angle analysis.

Referring to Figure 2 and considering the RULA score, it was observed that stations 4, 6, 7, 8, 9, and 10 exhibited nearly the highest level of risk. This conclusion was based on both the average and mode, which were both close to 7 and equal to 7, respectively, along with an overcrowded dispersion. The results of the REBE method weresimilar to those of the RULA method but indicated only a moderate level of risk.

Levene's test was employed to assess the equality of variances in the RULA and REBA scores. Figure 4 could display the results of the test for equal variances. The statistical test did not reject the null hypothesis that the variances were identical, as evidenced by p-values of 0.908 (multiple comparisons) and 0.858 (Levene’s test), both higher than typical alpha thresholds. The analysis indicated no statistically significant difference between the score variances calculated using the two approaches.

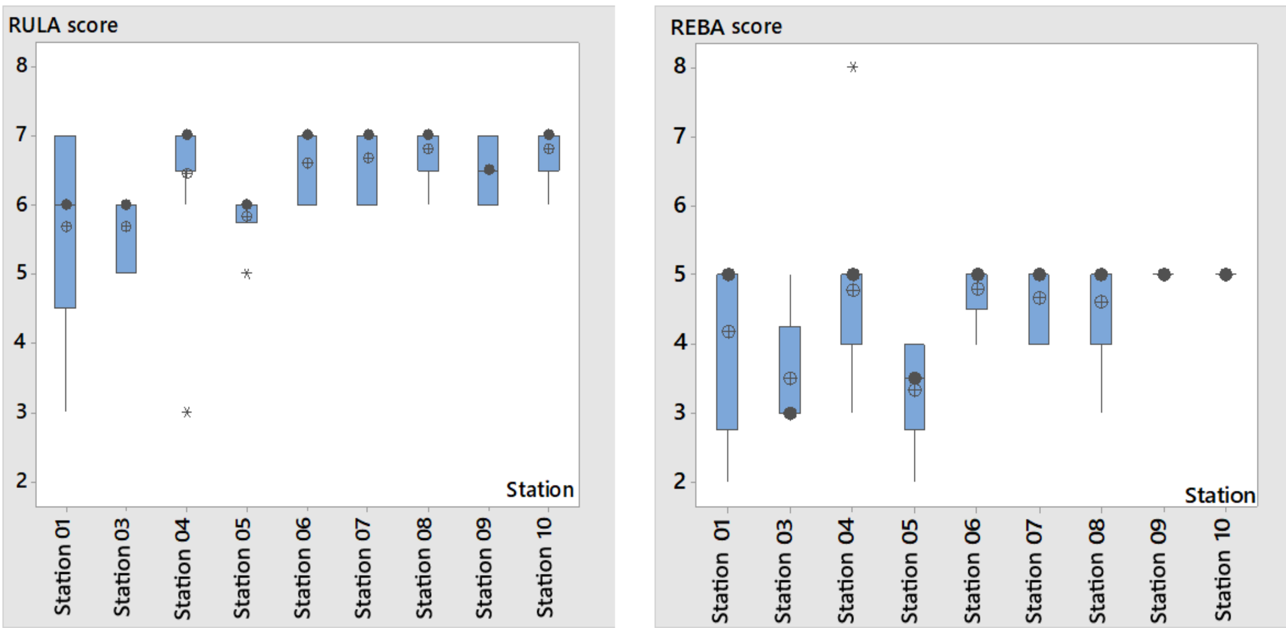
Table 2.
Scores on the ergonomics risk assessment before improvement.

Picture	Station 1		Station 3		Station 4		Station 5		Station 6		Station 7		Station 8		Station 9		Station 10	
	RULA	REBA	RULA	REBA	RULA	REBA	RULA	REBA	RULA	REBA	RULA	REBA	RULA	REBA	RULA	REBA	RULA	REBA
Pic #1	7	5	6	3	6	5	6	2	6	5	7	5	7	5	6	5	7	5
Pic #2	6	5	6	5	7	5	5	4	6	5	7	5	6	3	6	5	7	5
Pic #3	6	5	6	3	7	5	6	4	7	5	7	4	7	5	6	5	6	5
Pic #4	5	3	6	4	7	4	6	4	7	5	7	5	7	5	7	5	7	5
Pic #5	3	2	5	3	7	8	6	3	7	4	6	4	7	5	7	5	7	5
Pic #6	7	5	5	3	3	3	6	3			6	5			7	5		
Pic #7					7	4												
Pic #8					7	5												
Pic #9					7	4												

Table 3.
The overall average and standard deviation of risk assessment in group A before improvement.

Station	Number of gestures	RULA					REBA				
		Avg.	Mode	Min.	Max.	STD	Avg.	Mode	Min.	Max.	STD
Station 1: Inspection of goods received	6	5.67	6	3	7	1.51	4.17	5	2	5	1.33
Station 3: Boiling to clean up oil stains	6	5.67	6	5	6	0.52	3.5	3	3	5	0.84
Station 4: Use of hydrochloric acid	9	6.44	7	3	7	1.33	4.78	5	3	8	1.39
Station 5: Hydrochloric acid washing	6	5.83	6	5	6	0.41	3.33	4	2	4	0.82
Station 6: Metal blackening	5	6.6	7	6	7	0.55	5	5	5	5	0
Station 7: Blackening washing	6	6.67	7	6	7	0.52	4.67	5	4	5	0.52
Station 8: Water washing	5	6.8	7	6	7	0.45	4.6	5	3	5	0.89
Station 9: Drying	6	6.5	6, 7	6	7	0.55	5	5	5	5	0
Station 10: Oil dip	5	6.8	7	6	7	0.45	5	5	5	5	0
Overall average	-	6.3148	-	-	-	-	4.4259	-	-	-	-

Note: STD is an acronym denoting the standard deviation.



a) RULA score

b) REBA score

Figure 3.
Boxplots of RULA and REBA scores.
Note: The asterisk symbol indicates outliers in a Boxplot.

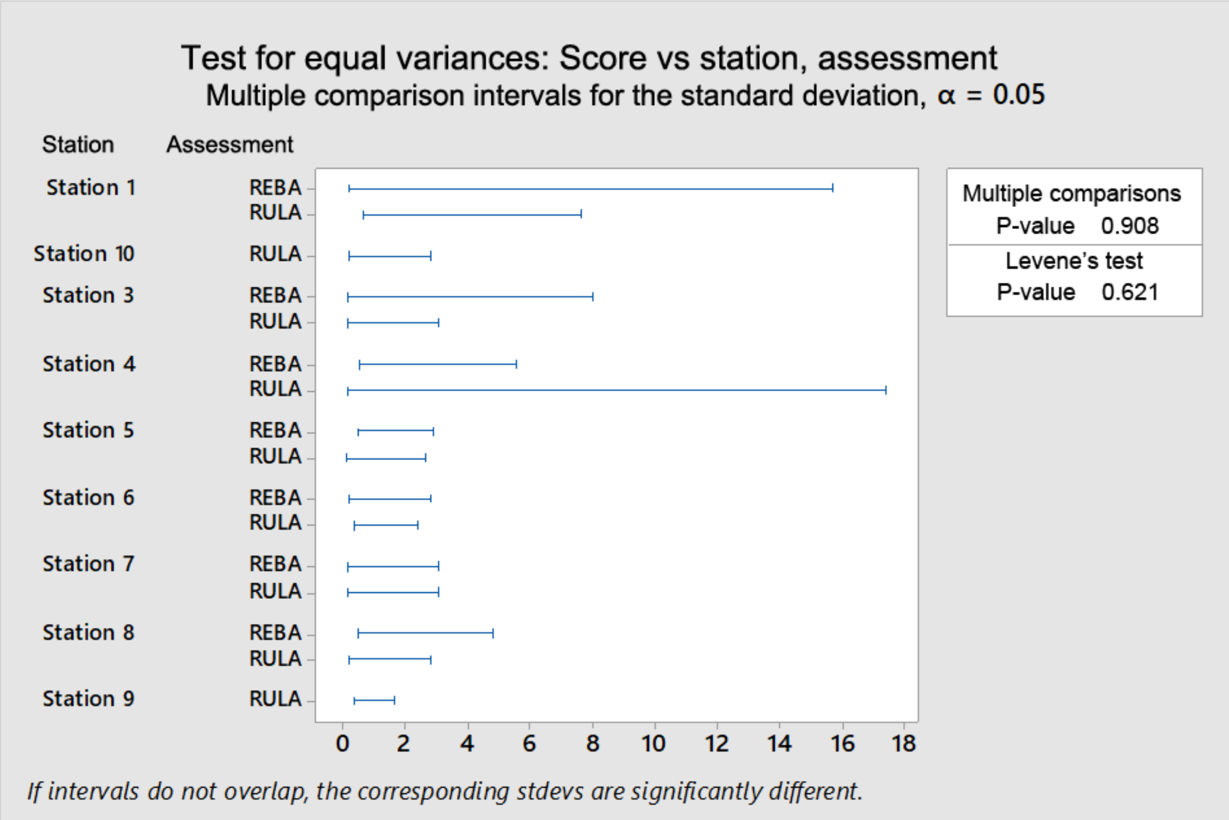


Figure 4.
Test for equal variances.

5. Summary and Discussion

This study examined the small-business work in the metal plating sector, such as surface coating, black plating, zinc phosphate plating, manganese phosphate plating, etc. This business primarily relied on physical labor with minimal machinery usage. Utilizing the CMDQ interview form, information was gathered from a group of employees involved in the blackened surface treatment process, emphasizing the need for a more thorough consideration of employee posture at work. Consequently, an ergonomic risk assessment was conducted for the company's employees.

The overall average RULA score obtained from the ergonomic risk assessment was 6.3148, indicating a high-risk level. Specifically, the blackened surface treatment process revealed emerging ergonomic issues. The REBA score, at 4.4259, pointed to a medium risk level, suggesting a need for further analysis and improvement. When comparing methods with identical work postures, the RULA approach demonstrated superior ability in identifying risk compared to the REBA method. However, both approaches produced variances that did not differ significantly when considering the dispersion of scores. In addition, the study's findings revealed a correlation between pain levels, assessed using the Cornell Musculoskeletal Discomfort Questionnaires (CMDQ), and risk scores derived from the RULA and REBA methods.

In the context of evaluating the efficacy of ergonomic risk assessment through mean risk scores, the outcomes aligned with findings from studies by Cremasco, et al. [28]; Yarandi, et al. [29] and Kee, et al. [30]. These studies suggested that the RULA method was capable of expeditiously identifying work-related risk assessments compared to the REBA method, facilitating the prompt implementation of solutions and the prevention of potential hazards arising from occupational activities. Nevertheless, it was imperative to note that scores derived from the REBA method necessitated a more assertive interpretation than the original standards.

Detailed analysis revealed that stations 4, 6, 7, 8, and 9 had the highest, considering both the RULA score average and the lowest score dispersion. Ergonomists or industrial engineers should prioritize improving these stations to ensure proper working postures and reduce the risk of bodily harm.

This specificity provides targeted insights into the ergonomic challenges and risks unique to this industry. The research paper establishes a foundation for future studies to build upon and potentially generalize findings to broader contexts within the metal coating or related industries.

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