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Ergonomic Risk Assessment of Construction Workers Using RULA, REBA, and NBM Methods: A Case Study in Bandung, Indonesia

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Abstract

Question: What are the main ergonomic risk factors that contribute to musculoskeletal disorders (MSDs) among construction workers performing physically demanding tasks?

Purpose: The purpose of this study is to analyze ergonomic risks in construction work by applying the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) methods, supported by the Nordic Body Map (NBM) questionnaire. The aim is to identify high-risk postures, quantify risk levels, and propose effective interventions to reduce physical strain and improve worker productivity.

Research Method: This study employed field observation and quantitative posture assessment conducted at a renovation project of PT Hutama Karya in Bandung, Indonesia. Data were collected through direct observation of 20 workers engaged in tasks such as bricklaying, rebar work, concrete pouring, and manual cement mixing. Each activity was evaluated using RULA and REBA scoring sheets, while the NBM questionnaire was used to identify musculoskeletal discomfort in specific body regions.

Findings: Manual cement mixing was found to have the highest ergonomic risk, with RULA and REBA scores exceeding 8 and NBM scores above 72, indicating very high musculoskeletal stress. Other activities—such as brick lifting and concrete pouring—showed medium to high risk levels. The findings confirm that awkward postures, repetitive motions, and heavy manual handling are dominant contributors to MSDs in construction sites.

Limitations: This study was limited to one project location and did not include mechanical or environmental stressors such as vibration or temperature. Broader site variations may yield different results.

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Implications: Failure to implement ergonomic improvements such as mechanical aids, posture training, and task rotation can increase injury risk, reduce productivity, and raise project costs. Integrating ergonomic assessments into construction risk management can significantly enhance safety and efficiency.

Value for authors: This study provides practical guidance on how to assess and manage ergonomic risks using combined RULA, REBA, and NBM methods—helping practitioners design safer, more efficient construction workplaces.

Keywords: ergonomics, body posture, RULA, REBA, musculoskeletal disorders, construction safety

Paper type: Case Study

Introduction

Construction work remains one of the most physically demanding and high-risk occupations worldwide (Zaitoun et al., 2024). Despite advances in technology and management systems, many construction activities still depend heavily on manual labor involving repetitive motions, awkward postures, and excessive physical effort (Prokhorov, 2018). These non-ergonomic practices contribute significantly to work-related musculoskeletal disorders (MSDs), leading to reduced worker well-being, declining productivity, and increased project costs (Fauzan Akhtar et al., 2025). In Indonesia, construction accidents continue to rise annually, with musculoskeletal injuries forming a large portion of occupational health cases (Bria et al., 2024). This situation underscores the need to integrate ergonomic risk management into construction practice as part of the broader commitment to continuous improvement and waste reduction core principles of Lean Construction (Colim et al., 2021).

Lean Construction emphasizes respect for people, value creation, and the elimination of non-value-adding activities (Moshood Adegbite, 2024). From an ergonomic perspective, poor body postures, unnecessary motions, and excessive physical strain represent a form of muda (waste) because they consume worker energy without generating value (Alsaffar & Ketan, 2018). Improving work postures and task design not only enhances safety but also supports flow efficiency and long-term sustainability (Tao et al., 2024). By identifying ergonomic risks and redesigning work processes, construction managers can reduce health-related downtime, improve workforce performance, and create a safer, more productive site environment (Sardinha et al., 2024).

In this paper, Lean Construction is understood as a socio-technical production and learning system that integrates reliable workflow, human commitment, and continuous improvement through PDCA, A3, and Kata routines (Abdelhamid & Everett, 2001; Ballard, 2000; Mossman, 2018). From this perspective, ergonomic risk is not only a health issue but a source of workflow unreliability, as physical fatigue and awkward motion destabilize task execution and disrupt production flow (Abdelhamid & Everett, 2001; Howell et al., 2002)

In line with Lean Construction principles, ergonomic assessment serves as a lean diagnostic tool to uncover inefficiencies embedded in human movement and workflow design. The integration of RULA (Rapid Upper Limb Assessment), REBA (Rapid Entire Body

Assessment), and the Nordic Body Map (NBM) questionnaire offers a data-driven framework for visualizing postural stress and quantifying physical efforts that do not add value. While previous studies have often applied these tools independently, few have combined them to form a comprehensive understanding of how ergonomic performance influences lean-based productivity outcomes in the construction industry.

This study aims to bridge that gap by evaluating ergonomic risks among construction workers at a renovation project in Bandung, Indonesia. By applying RULA, REBA, and NBM in an integrated manner, the research identifies sources of ergonomic waste, prioritizes corrective actions, and proposes lean-based ergonomic interventions. The findings are expected to not only improve worker well-being but also enhance operational efficiency and support the realization of waste free construction processes.

Research Method

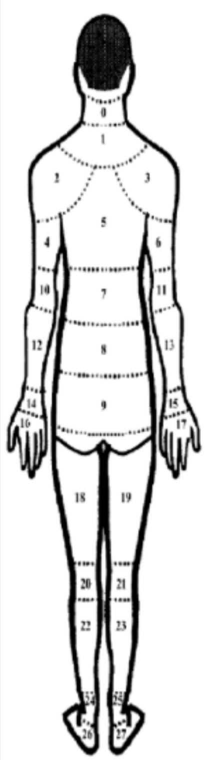
This research was designed as a field-based ergonomic assessment to identify, analyze, and mitigate physical risk factors affecting construction workers. The study was conducted at a renovation project managed by PT Hutama Karya in Bandung, Indonesia. The site was selected because it represents a typical medium-scale construction project with diverse manual tasks—conditions that often lead to postural strain and ergonomic inefficiency. The research was carried out over five months, from November 2024 to March 2025, involving twenty workers across various activities including bricklaying, reinforcement work, formwork, concrete pouring, plastering, and manual cement mixing.

A combination of observational analysis and self-reported data collection was employed. Three complementary tools were used to ensure robust results: the Rapid Upper Limb Assessment (RULA), the Rapid Entire Body Assessment (REBA), and the Nordic Body Map (NBM) questionnaire. RULA and REBA were applied through direct observation of workers during normal working hours, capturing postures related to bending, lifting, squatting, and carrying materials. Each worker was observed for at least fifteen minutes per task, and postures were analyzed using standardized scoring sheets as shown in Figure 1. The NBM questionnaire was distributed to assess subjective discomfort and pain experienced in 28 body regions. This combination allowed cross-validation between observed posture risks and perceived musculoskeletal symptoms.

This study followed a structured ergonomic evaluation framework consisting of four sequential phases: posture scoring, risk categorization, identification of high-risk tasks, and development of corrective strategies. These stages were designed to ensure that data collection and interpretation could directly support practical decision-making in the field.

- Posture Scoring
    - In this phase, each worker's movement and posture were recorded during typical work cycles, focusing on tasks such as lifting, bending, squatting, and reaching. The RULA method was used to assess the upper limbs, neck, and trunk, while REBA provided a comprehensive evaluation of whole-body postures. Every posture was analyzed using a standardized scoring sheet,

taking into account joint angles, static muscle loading, and external forces. The scoring produced a numerical value ranging from 1 (acceptable posture) to above 7 (urgent corrective action required). This approach provided an objective foundation for assessing the severity of postural strain.



No	Location	Grade of complaints			
0	Pain/stiff in the upper neck	A	B	C	D
1	Pain in the lower neck				
2	Pain in the left shoulder				
3	Pain in the right shoulder				
4	Pain in the left upper arm				
5	Pain in the back				
6	Pain in the right upper arm				
7	Pain in the waist				
8	Pain in the buttock				
9	Pain in the bottom				
10	Pain in the left elbow				
11	Pain in the right elbow				
12	Pain in the left lower arm				
13	Pain in the right lower arm				
14	Pain in the left wrist				
15	Pain in the right wrist				
16	Pain in the left hand				
17	Pain in the right hand				
18	Pain in the left thigh				
19	Pain in the right thigh				
20	Pain in the left knee				
21	Pain in the right knee				
22	Pain in the left calf				
23	Pain in the right calf				
24	Pain in the left ankle				
25	Pain in the right ankle				
26	Pain in the left foot				
27	Pain in the right foot				

Figure 1. Scoring Body Worker Questionnaire

- Risk Categorization
  - The numerical scores from RULA and REBA were then categorized into five risk levels—*negligible*, *low*, *medium*, *high*, and *very high*. Tasks with RULA scores above 6 or REBA scores above 8 were considered critical ergonomic risks, requiring immediate attention. In parallel, results from the Nordic Body Map (NBM) were analyzed to capture workers' subjective pain and discomfort levels. NBM scores above 72 indicated severe musculoskeletal stress, especially in the lower back, shoulders, neck, and knees. Combining both objective and subjective data allowed a comprehensive view of ergonomic conditions on-site.
- Identification of High-Risk Tasks
  - The next step involved mapping the results against specific construction activities to identify which tasks contributed most to postural risk. The analysis revealed that manual cement mixing, bricklaying, and rebar work

consistently generated high-risk scores across RULA, REBA, and NBM assessments. Common risk factors included prolonged trunk flexion, repetitive upper-limb movements, static kneeling, and overhead work. These findings made it possible to prioritize which activities required immediate ergonomic improvement, consistent with Lean Construction's focus on eliminating non-value-adding processes (*muda*).

Figure 2. Body Scoring RULA

- Development of Corrective Strategies
    - Based on the identified risks, targeted corrective actions were developed through the lens of *continuous improvement (kaizen)* and *respect for people*. The strategies were grouped into three categories:
        - Engineering controls: introducing mechanical aids (e.g., concrete mixers, wheelbarrows, adjustable scaffolds) to reduce manual workload and excessive bending.
        - Administrative controls: implementing job rotation, scheduled rest breaks, and ergonomic awareness training to reduce fatigue and improve posture habits.
        - Workplace layout improvement: repositioning material storage areas closer to work zones to minimize unnecessary movements and optimize flow efficiency.

- The combination of these interventions reflects Lean Construction principles—reducing waste in human effort, ensuring safer workflows, and enhancing value creation. This method provides a practical framework for integrating ergonomic analysis into daily construction management, transforming data into actionable improvement cycles.

Figure 3 illustrates the structured ergonomic assessment workflow used in this study. The process follows a lean continuous improvement logic, moving from field observation to posture scoring, task prioritization using combined thresholds, implementation of countermeasures, and follow-up learning.

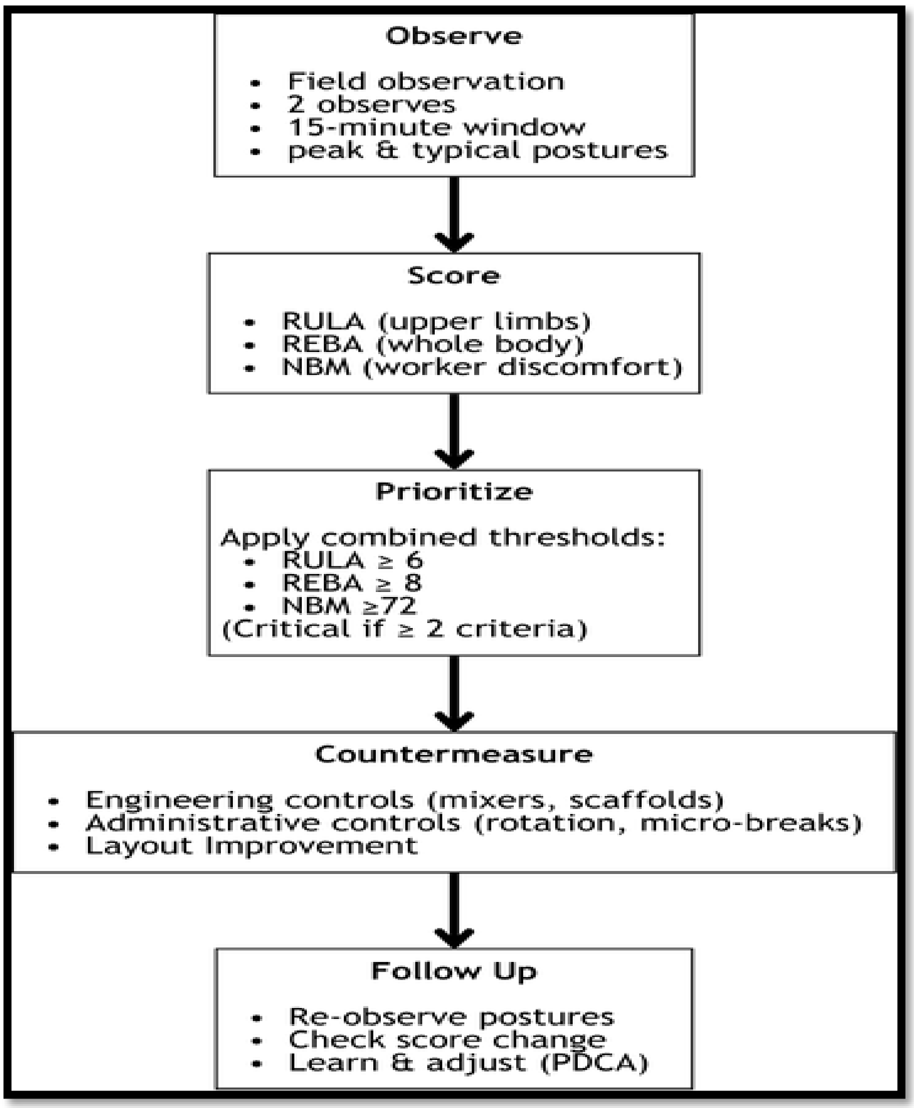


Figure 3. Ergonomic assessment workflow aligned with lean continuous improvement integrating RULA, REBA, and Nordic Body Map to support workflow reliability and respect for people.

This study applies the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) methods, complemented by the Nordic Body Map (NBM) questionnaire, to evaluate the ergonomic risks faced by construction workers at a renovation project in Bandung, Indonesia. The results are intended to help practitioners visualize the sources of ergonomic waste, prioritize corrective actions, and adopt lean-based ergonomic interventions that enhance both worker welfare and project outcomes. Detailed information on observer protocol, scoring thresholds, and the integration logic for RULA–REBA–NBM is provided in Appendix A to support reproducibility.

Result and Discussion

The ergonomic assessment revealed that construction activities at the Bandung project site present varied levels of postural risk depending on task type and work intensity. Data obtained from the combined use of the RULA, REBA, and NBM tools provided both quantitative and qualitative insights into how physical effort and postural strain influence worker well-being and productivity.

Table 1: High-risk construction tasks identified using combined RULA-REBA-NBM thresholds and corresponding lean countermeasures.

Task	Threshold Hit	Main Risk	Lean Countermeasure
Manual cement mixing	RULA≥6, REBA≥8, NBM≥72	Bent trunk, repetition	Portable mixer, layout change
Bricklaying	RULA≥6, REBA≥8	Shoulder/wrist load	Adjustable scaffold
Rebar work	REBA≥8	Static kneeling	Workstation redesign

Ergonomic Risk Levels and Worker Discomfort

The results shown in Table 1 indicate that manual cement mixing was the most critical task, with RULA and REBA scores exceeding 8 and NBM scores above 72, indicating very high ergonomic risk. Workers performing this task frequently maintained bent trunk positions, repetitive arm movements, and static lower-limb postures, leading to concentrated discomfort in the lower back, shoulders, and knees. Bricklaying and rebar installation activities also exhibited medium-to-high risk scores, with RULA values between 5–7 and REBA between 7–10. The most affected body regions were the neck, shoulders, and wrists, which correlate with repetitive lifting and reaching motions. Conversely, formwork and finishing activities showed moderate risks, as these tasks involve more varied postures and shorter repetitive cycles.

The pattern of musculoskeletal discomfort reported in the NBM questionnaire validated these findings. Over 70% of workers experienced recurring stiffness in the waist and upper back, while 55% reported pain in the shoulders and neck area. These conditions are consistent with previous ergonomic studies in construction, confirming that poor posture, repetition, and static loading are key contributors to work-related musculoskeletal disorders (WRMSDs) (Hajaghazadeh et al., 2019; Lop et al., 2019).

Table 2: Result Scoring RULA and REBA

No	Work Station	Worker	RULA Score	REBA Score
1	Reinforcement	A	5	9
2	Reinforcement	B	5	8
3	Reinforcement	C	6	8
4	Formwork	D	3	6
5	Formwork	E	7	11
6	Concrete	F	7	9
7	Concrete	G	7	7
8	Concrete	H	7	8
9	Concrete	I	7	6
10	Concrete	J	7	9
11	Concrete	K	7	7
12	Plastering / Rendering (Finishing)	L	7	9
13	Plastering / Rendering (Finishing)	M	7	5
14	Plastering	N	6	11
15	Plastering	O	6	8
16	Plastering	P	6	7
17	Ceramic	Q	7	9
18	Bricklaying	R	5	9
19	Bricklaying	S	7	8
20	Bricklaying	T	7	10

Risk Categorization and Lean Waste Analysis

By mapping ergonomic scores to Lean Construction principles, postural inefficiencies can be interpreted as a form of *muda*, specifically overexertion and unnecessary motion. Each excessive movement or prolonged static posture represents a hidden waste of human energy that adds no value to the construction process. For example, manual cement mixing involved redundant bending and carrying motions that could be eliminated through the use of simple mechanical mixers. Similarly, the repetitive lifting of bricks without adjustable scaffolding created ergonomic waste in the form of fatigue and micro-delays in work flow. Recognizing ergonomic risks through a lean lens thus enables project managers to treat human energy as a critical production resource, not an expendable cost (Afonso et al., 2022a; Aglan Gokler et al., 2024).

Identification of High-Risk Tasks and Improvement Priorities

The identification of high-risk tasks was based on the combined thresholds: RULA ≥ 6, REBA ≥ 8, and NBM ≥ 72. Three activities consistently met these criteria: manual cement mixing, bricklaying, and rebar work. These activities were prioritized for intervention due to their high frequency and physical intensity. Lean improvement workshops were held with site supervisors and workers to discuss feasible solutions. Using kaizen principles, the team proposed (1) introducing mechanical aids such as small-capacity concrete mixers and adjustable trolleys; (2) rearranging material storage areas to reduce unnecessary walking distance; and (3) implementing brief micro-breaks and stretching routines during work cycles. Each solution aimed to minimize motion waste, reduce fatigue, and sustain steady production flow without compromising output quality (Kulkarni & Devalkar, 2019; Tandazo et al., 2025).

Development of Corrective Strategies and Lean Outcomes

Applying the lean framework to ergonomic management produced measurable improvement opportunities. Engineering controls such as the adoption of concrete mixers could reduce RULA and REBA scores by up to two points, indicating a shift from high to moderate risk levels. Administrative controls, including task rotation and ergonomic awareness training, fostered a sense of ownership and respect for people, allowing workers to contribute directly to safety improvement. The redesign of workstations to reduce bending frequency aligns with the lean goal of flow efficiency where physical motion, material movement, and information flow are synchronized. Collectively, these strategies reflect that ergonomic enhancement is not an isolated health initiative but an integrated productivity improvement tool (Afonso et al., 2022b; Colim et al., 2021). As an initial validation signal, after introducing a portable concrete mixer in one work zone, observed peak trunk flexion during manual cement mixing was visibly reduced, and the representative RULA score decreased from 8 to 6. This qualitative before–after observation indicates that simple engineering controls can meaningfully lower ergonomic risk while stabilizing task execution and supporting smoother workflow.

Discussion and Implications for Lean Construction Practice

The findings confirm that ergonomic risks in construction represent both a human and operational challenge. High postural loads translate into fatigue, micro-stoppages, and rework, all of which disturb workflow continuity and increase hidden costs. From a lean perspective, ergonomic waste is a silent constraint that limits the ability of teams to achieve continuous flow. Therefore, incorporating ergonomic risk analysis (RULA–REBA–NBM) into daily site management supports visual management, enabling supervisors to identify, prioritize, and eliminate sources of waste that arise from inefficient body motion. The results demonstrate that lean-based ergonomics not only protect workers' health but also drive tangible performance improvements, such as smoother production rhythm, fewer interruptions, and higher morale. This reinforces the principle that respect for people is inseparable from process efficiency both are prerequisites for achieving truly lean and sustainable construction systems (Brito et al., 2018; Kumar & Thangavelu, 2024).

Conclusion and Recommendations

This study evaluated ergonomic risks among construction workers using a combination of the Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and Nordic Body Map (NBM) methods. The results showed that several construction tasks expose workers to high levels of postural stress and musculoskeletal discomfort. Manual cement mixing was identified as the most critical activity, with RULA and REBA scores exceeding 8 and NBM values above 72, indicating a very high ergonomic risk. Other activities, such as bricklaying and rebar installation, also exhibited moderate-to-high risk levels due to repetitive movements and awkward postures. These findings confirm that poor ergonomics is a significant contributor to physical strain, productivity loss, and safety risks in construction work.

From a Lean Construction perspective, ergonomic inefficiencies can be interpreted as a form of muda—the waste of human energy through unnecessary motion, overexertion, or fatigue. Each instance of poor posture represents a potential loss in flow efficiency and worker value. Therefore, managing ergonomic risk is not merely a health initiative but a strategic improvement effort aligned with lean goals of eliminating waste and creating sustainable value. By treating ergonomic assessment as part of visual management, site managers can identify invisible wastes and continuously refine workflows to achieve smoother and safer operations.

To address the identified risks, three levels of corrective action are recommended. First, implement engineering controls such as the use of concrete mixers, wheelbarrows, and adjustable scaffolding to reduce physical load. Second, apply administrative controls—job rotation, micro-breaks, and ergonomic awareness programs—to balance workloads and maintain worker alertness. Third, improve workplace layout by optimizing material flow and minimizing unnecessary walking or bending. Together, these interventions form an integrated lean-ergonomic framework that aligns worker safety with productivity.

Future studies are encouraged to expand this approach by incorporating digital tools such as motion capture, wearable sensors, or Building Information Modeling (BIM)-based ergonomics simulations to strengthen data precision and enable real-time feedback. Ultimately, this research demonstrates that ergonomics and lean construction share a common goal: to respect people by designing work that is efficient, safe, and sustainable—where every movement adds value and every worker's well-being becomes a measure of operational excellence.

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Appendix A - Method Traceability

This appendix provides detailed information to support the reproducibility and transparency of the ergonomic assessment protocol used in this study, as recommended by LCJ reviewers.

A1. Observer Protocol

Two trained observers conducted all ergonomic assessments independently. Both observers had prior experience using RULA and REBA methods in construction settings. Observations were carried out during normal working hours without interrupting ongoing activities. To reduce observer bias, both assessors discussed scoring criteria in advance and cross-checked a subset of observations to ensure consistency.

Each worker was observed within a 15-minute observation window for each task. This duration was selected to capture representative postural patterns while remaining practical for active construction environments.

A.2 Posture Selection: Peak and Typical Postures

For each task, two posture types were recorded:

- **Peak posture**: the most ergonomically demanding posture observed during the task (e.g., maximum trunk flexion or highest shoulder elevation).
- **Typical posture**: the posture most frequently adopted during the task execution.

Both posture types were scored using RULA and REBA. When scores differed, the **higher score** was used for risk classification to reflect conservative safety assessment.

A3. Scoring Assumptions

External load and force assumptions were based on direct observation and typical material weights used on-site (e.g., cement bags, bricks, reinforcement bars). Static muscle loading and repetition were considered according to standard RULA and REBA guidelines.

The Nordic Body Map (NBM) questionnaire was administered in Indonesian to ensure comprehension. Respondents rated discomfort across 28 body regions using a four-point scale. Total scores ranged from 28 to 112, with higher scores indicating greater musculoskeletal discomfort.

A4. Threshold Rule and Integration Logic

To prioritize tasks requiring intervention, a combined threshold rule was applied:

A task is classified as “critical” if at least two of the following conditions are met:

- RULA ≥ 6
- REBA ≥ 8
- NBM ≥ 72

This integration rule allows ergonomic risk to be interpreted not only through observed posture but also through worker-reported discomfort, supporting a lean perspective that links human effort to workflow reliability.

A5. Example of RULA-REBA Scoring Sheet (Illustrative)

Table A1 presents an illustrative example of posture scoring for manual cement mixing.

Table A1. Example of RULA-REBA Scoring for Manual Cement Mixing

Body Segment	Observed Condition	RULA Score	REBA Score
Upper arm	**Elevated >45°**	**4**	**3**
Lower arm	**Extended**	**2**	**2**
Wrist	**Deviated**	**2**	**2**
Neck	**Flexed >20°**	**3**	**2**
Trunk	**Flexed >60°**	**4**	**4**
Legs	**Static standing**	**1**	**2**
Final score	**–**	**8**	**9**

Based on the combined RULA–REBA–NBM thresholds, this task was classified as critical and prioritized for corrective action.