

# Analysis of Musculoskeletal Complaints and Work Posture Risks in the Rear Wheel Hub Plug Welding Process Using NBM REBA and RULA

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## Abstract.

*The plug welding activity on Wheel Hub Rear components in the welding division of PT SSC Works Surabaya is performed repetitively under working postures that may impose physical demands on operators. This study aimed to analyze musculoskeletal complaints using the Nordic Body Map (NBM), evaluate working posture risks using the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA), and formulate ergonomic improvement recommendations. A descriptive case study approach was applied to seven plug welding operators. The NBM questionnaire was administered to all operators, while REBA and RULA assessments were conducted on Operator 1 based on the availability of adequate postural documentation. The NBM results showed that all operators experienced musculoskeletal complaints, with total scores ranging from 50 to 79. Two operators were classified as having a high level of complaints, while five were classified as moderate. The most prominent complaint was found in the right wrist, with a total score of 27, followed by the right upper arm, right lower arm, and right hand, each with a score of 25. The postural assessment of Operator 1 resulted in a REBA score of 11, indicating a very high risk requiring immediate action, and a RULA score of 7, indicating the need for immediate investigation and changes. Based on these findings, the proposed ergonomic improvements include an Adjustable foot platform, cable hanger, and active rest. The Adjustable foot platform is designed using D5 anthropometric data with an adjustable height mechanism to help reduce the need for trunk flexion during the welding process.*

**Keywords:** Ergonomics; plug welding; Nordic Body Map; REBA and RULA.

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## I. INTRODUCTION

Ergonomics is a crucial aspect of work systems because it relates to the alignment between worker abilities, job demands, and the facilities used. A mismatch between these elements can cause workers to perform activities in unnatural postures, maintain certain positions, or perform repetitive movements, increasing the risk of musculoskeletal disorders. Tarwaka and Bakri[1] explains that the application of ergonomics is necessary to create working conditions that suit human capabilities and limitations. This issue becomes crucial in manual work such as welding, as the worker's body position often adjusts to the shape, size, and location of the object being worked on.

This condition was found during the plug welding activity of the Rear Wheel Hub component in the welding division of PT SSC Works Surabaya. The component being worked on was approximately 1.3 m high and in diameter, while several welding points were positioned low, close to the floor. One hole required approximately 2–3 minutes to complete, and under normal working conditions, an operator could complete approximately 50 holes in a day. This characteristic caused the operator to repeatedly adjust his body position relative to the welding point. Based on initial observations and communication with the operator, after completing the work for a certain duration, complaints arose in the neck, back, arms, and legs. This condition indicates the need for an ergonomic evaluation of the plug welding activity being carried out.



**Fig. 1.**Condition of plug welding activity on the Rear Wheel Hub component

Ergonomic risks in welding work have also been a concern in several previous studies. Larasati et al.[2]used REBA to evaluate the posture of welding workers and obtain the level of risk that requires corrective action. Pratama et al.[3]shows that several stages of work in the welding workshop are in the high to very high risk category based on the REBA and RULA assessments. Meanwhile, Ayutatila and Islami[4]used both methods to evaluate the posture of welding workers in a pipe workshop. The results of this study indicate that postural characteristics during the welding process are a factor that needs to be considered in efforts to reduce the risk of musculoskeletal disorders.

The use of more than one assessment method is also carried out in various types of work. Pratama, Fahnury, and Rizqi[5]used REBA and RULA to identify the risk of Musculoskeletal Disorders (MSDs) in Air Conditioning (AC) technicians and found variations in risk levels based on the activities and work postures performed. Purwanto et al.[6]developed an integrated approach using RULA, REBA, and OWAS to evaluate ergonomic risks while supporting workstation improvements. In a context closer to this research, Firdaus and Rizqi[7]applied NBM, REBA, and RULA to welding work and found musculoskeletal complaints and work postures that required corrective action. An approach that combined worker complaints and posture assessment was also used by Sundari et al.[8]through NBM and REBA as the basis for designing work facilities.

These studies indicate that NBM, REBA, and RULA have been used in various work activities, including welding. Therefore, this study does not consider the combination of the three methods as novel. The differences in this study lie in the characteristics of the plug welding activity of the Wheel Hub Rear component, namely the relatively large object size, the low position of several welding points, the large number of work points, and the need for the operator to adjust body position when controlling the welding torch. These characteristics create working conditions that require special evaluation. NBM is used to describe the location and level of complaints experienced by the operator, while REBA and RULA are used to evaluate postural risks based on actual conditions. The results of these three assessments are then used as a basis for formulating ergonomic improvement proposals appropriate to the work conditions.

Based on the description, this study aims to analyze the musculoskeletal complaints of plug welding operators using the Nordic Body Map (NBM), evaluate the risk of work posture using the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA), and formulate proposals for ergonomic improvements in plug welding activities of Wheel Hub Rear components at PT SSC Works Surabaya.

## **II. METHOD**

### **2.1 Research Design and Subjects**

This study uses a descriptive design with a case study approach on the plug welding activity of the Wheel Hub Rear component in the welding division of PT SSC Works Surabaya. Data collection was conducted on February 23–28, 2026. The research subjects consisted of seven plug welding operators who had at least one year of work experience in the welding division. All operators were involved in collecting data on

musculoskeletal complaints using the Nordic Body Map (NBM), while posture assessment using the Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) was carried out on Operator 1 based on the availability of adequate posture documentation.

## 2.2 Data Collection

The research data were obtained through observations of plug welding activities, documentation of work postures, and completion of the NBM questionnaire by all operators. Observations were conducted to obtain a picture of the actual conditions during the welding process, including the operator's body position when reaching the work point and controlling the welding torch. Posture documentation was then used as the basis for the REBA and RULA assessments on Operator 1. Data from the three approaches were used descriptively and complementary, not to test statistical relationships between methods. This is because NBM was applied to seven operators, while REBA and RULA were conducted on one operator based on available posture documentation.

## 2.3 Nordic Body Map (NBM)

The Nordic Body Map was used to identify the location and level of musculoskeletal complaints experienced by operators. Data were analyzed by summing the scores on 28 body parts to obtain a total score for each operator. In addition to the total score, the distribution of scores for each body part was analyzed to determine the body part that showed the most dominant complaints. Referring to Tarwaka and Bakri [1], the total NBM score was classified into four levels of complaints, namely 28–49 in the low category, 50–70 in the moderate category, 71–90 in the high category, and 91–112 in the very high category.

| No | Jenis keluhan            | Pekerja |   |   |   |
|----|--------------------------|---------|---|---|---|
|    |                          | 1       | 2 | 3 | 4 |
| 0  | Leher bagian atas        |         |   |   |   |
| 1  | Leher bagian bawah       |         |   |   |   |
| 2  | Bahu kiri                |         |   |   |   |
| 3  | Bahu kanan               |         |   |   |   |
| 4  | Lengan atas kiri         |         |   |   |   |
| 5  | Punggung                 |         |   |   |   |
| 6  | Lengan atas kanan        |         |   |   |   |
| 7  | Pinggang                 |         |   |   |   |
| 8  | Bokong                   |         |   |   |   |
| 9  | Pantat                   |         |   |   |   |
| 10 | Siku kiri                |         |   |   |   |
| 11 | Siku kanan               |         |   |   |   |
| 12 | Lengan bawah kiri        |         |   |   |   |
| 13 | Lengan bawah kanan       |         |   |   |   |
| 14 | Pergelangan tangan kiri  |         |   |   |   |
| 15 | Pergelangan tangan kanan |         |   |   |   |
| 16 | Tangan kiri              |         |   |   |   |
| 17 | Tangan kanan             |         |   |   |   |
| 18 | Paha kiri                |         |   |   |   |
| 19 | Paha kanan               |         |   |   |   |
| 20 | Lutut kiri               |         |   |   |   |
| 21 | Lutut kanan              |         |   |   |   |
| 22 | Betis kiri               |         |   |   |   |
| 23 | Betis kanan              |         |   |   |   |
| 24 | Pergelangan kaki kiri    |         |   |   |   |
| 25 | Pergelangan kaki kanan   |         |   |   |   |
| 26 | Kaki kiri                |         |   |   |   |
| 27 | Kaki kanan               |         |   |   |   |

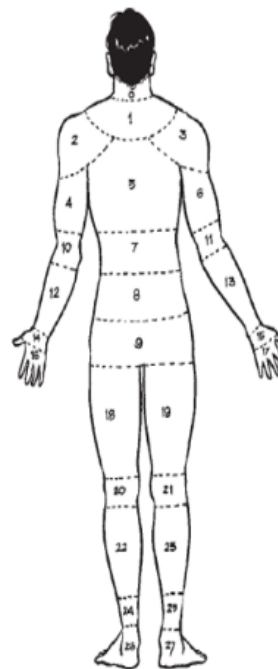
Keterangan:

1 = tidak sakit

3 = sakit

2 = agak sakit

4 = sangat sakit



**Fig. 2.**NBM Questionnaire

Source ; <https://repository.ub.ac.id/id/eprint/9190/9/LAMPRAN.pdf>

## 2.4 Rapid Entire Body Assessment (REBA)

REBA was used to evaluate the risk level of Operator 1's body posture during plug welding activities. Hignett and McAtamney[9] developed REBA as an assessment method that considers the position of several body parts, loads or forces, grip quality (coupling), and characteristics of work activities. Assessments were conducted on group A, consisting of the neck, trunk, and legs, and group B, which included the upper arms, forearms, and wrists. Scores from both groups were combined and adjusted for activity factors to obtain the final REBA score.

**Nawo Solution** **REBA Method** Find the full guide here: 

Name: \_\_\_\_\_ First Name: \_\_\_\_\_ Date: \_\_\_\_\_

Workstation: \_\_\_\_\_

### A. Neck, trunk and legs analysis

**Step 1** Locate neck position  
Neck in lateral flexion: Add +1  
Neck in axial rotation: Add +1  
Score: \_\_\_\_\_

**Step 2** Locate trunk position  
Trunk in axial rotation: Add +1  
Trunk in lateral flexion: Add +1  
Score: \_\_\_\_\_

**Step 3** Locate legs position  
ADJUSTMENTS:  
Feet on a surface between 30° and 60°: Add +1  
Feet on a surface greater than 60°: Add +2  
Legs are in bipodal support: +1  
Legs are in monopodal support: +2  
Score: \_\_\_\_\_

**Step 4** Posture Score A  
Using the values from steps 1 to 4, find the score in table A.  
Score: \_\_\_\_\_

| Trunk | Neck |   |   |   | Legs |   |   |   |
|-------|------|---|---|---|------|---|---|---|
|       | 1    | 2 | 3 | 4 | 1    | 2 | 3 | 4 |
| 1     | 1    | 2 | 3 | 4 | 1    | 2 | 3 | 4 |
| 2     | 2    | 3 | 4 | 5 | 2    | 3 | 4 | 5 |
| 3     | 3    | 4 | 5 | 6 | 3    | 4 | 5 | 6 |
| 4     | 4    | 5 | 6 | 7 | 4    | 5 | 6 | 7 |
| 5     | 5    | 6 | 7 | 8 | 5    | 6 | 7 | 8 |

**Step 5** Effort and load score  
Load less than 5kg: 0  
Load between 5kg and 10kg: +1  
Load greater than 10kg: +2  
If necks, violent posture are changing or high repetitiveness: Add +1  
Score: \_\_\_\_\_

**Step 6** Neck, trunk and legs score  
Add the values from steps 4 to 5 to obtain the Neck, Trunk and Legs score corresponding to the rows in table C.  
Score: \_\_\_\_\_

### B. Shoulder, elbow and wrist analysis

**Step 7** Locate shoulder position  
Shoulder rotation: Add +1  
Shoulder abducted: Add +1  
If the shoulder is supported or the person is leaning: Remove -1  
Score: \_\_\_\_\_

**Step 8** Locate elbow position  
Score: \_\_\_\_\_

**Step 9** Locate wrist position  
If ulnar/radial wrist deviation: Add +1  
Score: \_\_\_\_\_

**Step 10** Posture Score B  
Using the values from steps 7 to 9, find the score in table B.  
Score: \_\_\_\_\_

**Step 11** Grip score  
The hand hold is good with hands: 0  
The hand hold is acceptable: Add +1  
The hand hold is not acceptable but possible: Add +2  
The hand hold is dangerous: Add +3  
Score: \_\_\_\_\_

**Step 12** Shoulder, elbow and wrist score  
Add the values from steps 10 to 11 to obtain the Shoulder, Elbow and Wrist score corresponding to the columns in table C.  
Score: \_\_\_\_\_

**REBA final score**  
Table C score + Activity score: \_\_\_\_\_

| Score | Risk level                                        |
|-------|---------------------------------------------------|
| 1     | Negligible risk - no action required              |
| 2-3   | Low risk - change may be required                 |
| 4-7   | Medium risk - vigilance, improvements to consider |
| 8-10  | High risk - improvements needed                   |
| 11-15 | Very high risk - immediate response               |

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Fig. 3. REBA Employee Assessment Worksheet

Source ; [REBA Method - Ergonomic assessment method - Nawo Solution](#)

The interpretation of REBA scores is divided into five risk levels, namely a score of 1 indicates negligible risk, a score of 2–3 indicates low risk, a score of 4–7 indicates moderate risk, a score of 8–10 indicates high risk, while a score of 11–15 indicates very high risk and requires immediate action.

### 2.5 Rapid Upper Limb Assessment (RULA)

RULA is used as an additional assessment to evaluate postural risks in the upper limbs, neck, and trunk of Operator 1. McAtamney and Corlett[10] developed RULA as an assessment method to identify occupational posture exposures associated with the risk of upper limb disorders. The assessment considers the position of the upper arm, forearm, wrist, wrist rotation, neck, trunk, legs, muscle activity, and the load or force experienced during the activity.

**Nawo Solution** **RULA Method** Find the full guide here: 

Name: \_\_\_\_\_ First Name: \_\_\_\_\_ Date: \_\_\_\_\_

Workstation: \_\_\_\_\_

### A. Shoulder, elbow and wrist analysis

**Step 1** Locate shoulder position  
Shoulder rotation: Add +1  
Shoulder abducted: Add +1  
If the shoulder is supported or the person is leaning: Remove -1  
Score: \_\_\_\_\_

**Step 2** Locate elbow position  
If the forearm is working against a load or is out of body: Add +1  
Score: \_\_\_\_\_

**Step 3** Locate wrist position  
If a radial or ulnar deviation: Add +1  
Score: \_\_\_\_\_

**Step 4** Wrist pronosupination  
Wrist is in neutral: +1  
Wrist is at or near end of range: +2  
Score: \_\_\_\_\_

**Step 5** Posture Score A  
Using the values from steps 1 to 4, find the score in table A.  
Score: \_\_\_\_\_

**Step 6** Muscle activity  
If posture is held static for more than 10 minutes or if the action is repeated more than 4 times per minute: Add +1  
Score: \_\_\_\_\_

**Step 7** Effort and load score  
Load less than 2kg (10 min intermittently): 0  
Load between 2kg and 5kg (10 min intermittently): Add +1  
Load between 5kg and 10 kg (static posture or repeated): Add +2  
Load greater than 10 kg with repetition or duration: Add +3  
Score: \_\_\_\_\_

**Step 8** Shoulder, elbow and wrist score  
Add the values from steps 5 to 7 to obtain the Shoulder, Elbow and Wrist score corresponding to the rows in table C.  
Score: \_\_\_\_\_

### B. Neck, trunk and legs analysis

**Step 9** Locate neck position  
Neck in axial rotation: Add +1  
Neck in lateral flexion: Add +1  
Score: \_\_\_\_\_

**Step 10** Locate trunk position  
Trunk in axial rotation: Add +1  
Trunk in lateral flexion: Add +1  
Score: \_\_\_\_\_

**Step 11** Legs  
Legs are in bipodal support: +1  
Legs are in monopodal support: +2  
Score: \_\_\_\_\_

**Step 12** Posture Score B  
Use the values from steps 9 to 11, find the score in table A.  
Score: \_\_\_\_\_

**Step 13** Muscle activity  
If posture is held static for more than 10 minutes or if the action is repeated more than 4 times per minute: Add +1  
Score: \_\_\_\_\_

**Step 14** Neck, trunk and legs score  
Add the values from steps 12 to 13 to obtain the Neck, Trunk and Legs score corresponding to the columns in table C.  
Score: \_\_\_\_\_

**RULA final score**  
Table C score: \_\_\_\_\_

| Score | Risk level                                        |
|-------|---------------------------------------------------|
| 1-2   | Negligible risk - no action required              |
| 3-4   | Low risk - change may be required                 |
| 5-6   | Medium risk - vigilance, improvements to consider |
| 7     | High risk - immediate response                    |

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Fig. 4. RULA Employee Assessment Worksheet

Source ; [RULA Method - Ergonomic analysis method - Nawo Solution](#)

The final RULA score is interpreted into four action levels. Scores of 1–2 indicate a posture that is acceptable if not maintained or repeated for a prolonged period; scores of 3–4 indicate a need for further investigation; scores of 5–6 indicate a need for investigation and change in the near future; and scores of 7 indicate a need for immediate investigation and change.

## 2.6 Formulation of Ergonomic Improvement Proposals

Ergonomic improvement proposals were formulated based on the results of complaint identification using NBM, posture assessment results using REBA and RULA, and the actual conditions of plug welding activities. Findings on body parts with dominant complaints and posture aspects indicating high risk were used as the basis for determining the direction of improvement. This approach was used to obtain proposals that were not only based on the values of each method, but also took into account the characteristics of the work observed in the field.

The proposed improvements focused on three main aspects: adjusting body position relative to the work area, reducing equipment load on the upper limbs, and reducing exposure to static postures and repetitive activities. The improvements analyzed in the study included adjustable foot platforms, cable hangers, and active rests.

## III. RESULTS AND DISCUSSION

### 3.1 Nordic Body Map (NBM) Results

The results of the Nordic Body Map (NBM) showed that all operators experienced musculoskeletal complaints at varying levels. The total NBM score for the seven operators ranged from 50 to 79. Based on the classification used in the study, five operators were in the moderate category and two operators were in the high category. Operators 2 and 4 obtained the highest score, 79, while Operator 7 obtained the lowest score, 50. These data indicate that musculoskeletal complaints were not only found in one operator, but appeared in all respondents involved in the study.

**Table 1.** Score and level of musculoskeletal complaints based on NBM

| Operator   | Age (years) | NBM Score | Category  |
|------------|-------------|-----------|-----------|
| Operator 1 | 33          | 64        | Currently |
| Operator 2 | 32          | 79        | Tall      |
| Operator 3 | 30          | 58        | Currently |
| Operator 4 | 28          | 79        | Tall      |
| Operator 5 | 27          | 67        | Currently |
| Operator 6 | 22          | 68        | Currently |
| Operator 7 | 19          | 50        | Currently |

Differences in scores for each operator reflect variations in the level of complaints experienced during work. However, these differences cannot be used to conclude a relationship between age and complaint levels due to the descriptive nature of this study and the limited number of respondents.

Further analysis of each body part revealed that the most predominant complaint was in the right wrist, with a total score of 27. Six of the seven operators rated this area as very painful. The next most common complaints were in the right upper arm, right forearm, and right hand, each with a score of 25, while the right shoulder and waist each received a score of 23.

**Table 2.** Distribution of NBM complaints in body parts with the highest scores

| Parts of body   | Total score | Dominant findings                  |
|-----------------|-------------|------------------------------------|
| Right wrist     | 27          | 6 out of 7 operators are very sick |
| Right upper arm | 25          | High complaints                    |
| Right forearm   | 25          | High complaints                    |
| Right hand      | 25          | High complaints                    |
| Right shoulder  | 23          | Complaints are quite high          |
| Waist           | 23          | Complaints are quite high          |

The predominance of complaints on the right side aligns with the characteristics of plug welding, where the right hand is used to control the welding torch. In addition to maintaining the torch position, the operator adjusts the direction of the hand and wrist while following the welding point. Meanwhile, complaints around the waist require attention, along with the relatively low working position, requiring the operator to adjust the position of the torso throughout the process.

The complaint pattern has similarities with Firdaus and Rizqi's research.[7]In welding work, complaints were also found to be prominent in the right hand. Gifari and Ismiyah[11]In the context of production work, dominant complaints were also found in the back, waist, shoulders, and wrists based on the NBM. This similarity indicates that the upper limbs and trunk are areas that require attention when activities involve non-neutral postures and repetitive work. However, the NBM results in this study describe subjective operator complaints and cannot be used to establish a direct cause-and-effect relationship.

### 3.2 Assessment Results *Rapid Entire Body Assessment*(REBA)

The REBA assessment was conducted on Operator 1 based on posture documentation during plug welding activities. Measurement results showed that the neck was at a position of approximately  $47^\circ$  downwards, the torso was bent approximately  $32^\circ$  forward, and the legs were in a bent position. In the upper limbs, the upper arm formed an angle of approximately  $96^\circ$  with the shoulder raised, the forearm approximately  $118^\circ$ , while the wrist was in a bent position and experienced a rotating motion during the welding process.



**Fig. 5.**Operator Body Posture

Based on the REBA calculation, Group A obtained a score of 7 and Group B obtained a score of 8. The combination of the two groups resulted in a Table C score of 10. After taking into account the activity factor of 1, the final REBA score was 11. This value is included in the very high risk category and indicates the need for immediate corrective action.

**Table 3.**REBA Operator 1 Assessment Results

| Component        | Score                                       |
|------------------|---------------------------------------------|
| Group A          | 7                                           |
| Group B          | 8                                           |
| Table C          | 10                                          |
| Activity         | 1                                           |
| REBA final score | 11                                          |
| Interpretation   | Very high risk requires immediate response. |

A high REBA score doesn't originate from a single body segment, but rather from the combined posture of the neck, torso, legs, arms, and wrists. A hunched torso and a downward-facing neck are associated with the operator's need to approach the welding point at a low position. At the same time, the raised upper arm

and non-neutral wrist position indicate additional demands placed on the operator when maintaining and guiding the welding torch. Repetitive activity factors contribute to the overall score.

These results show a pattern consistent with several previous welding studies. Larasati et al.[2]obtained a REBA score of 8 in workers who performed welding in a squatting and bending position. Pratama et al.[3]got a REBA score of 10 at the welding stage, while Ayutatila and Islami[4]also found a level of risk that requires improvement in welding workers. Firdaus and Rizqi[7]even reported one welding worker with a REBA score of 11.

Putra and Khatamy[12]also found high levels of ergonomic risk in catwalk welding activities using REBA and QEC and directed improvements to more ergonomic workstations. Findings from several welding contexts suggest that the position of the workpiece and the operator's need to bend, reach, or maintain certain body parts can be important factors in high posture assessment results. However, scores between studies are not directly comparable because each activity has different characteristics of the object, facilities, duration, and working conditions.

### 3.3 Rapid Upper Limb Assessment (RULA) Results

RULA assessment was conducted on Operator 1 to obtain a more focused picture of the upper limbs, neck, and trunk. The measurement results showed that the upper arm was at an angle of more than 90° and the shoulder was raised, resulting in a final score of 5. The lower arm formed an angle of approximately 118° with a score of 3, while the wrist was in a bent and deviated position, resulting in a score of 4. Wrist rotation received a score of 2 because it was near the end of its range of motion.

After taking into account posture, muscle activity and workload, the upper limb group produced a Shoulder, Elbow and Wrist Score of 11. Meanwhile, the neck, trunk and legs assessment produced a score of 8. The combination of the two groups produced a final RULA score of 7, indicating the need for immediate investigation and changes to working conditions.

**Table 4.**RULA Assessment Results for Operator 1

| Component                        | Score                                       |
|----------------------------------|---------------------------------------------|
| Upper arm                        | 5                                           |
| Forearm                          | 3                                           |
| Wrist                            | 4                                           |
| Wrist twist                      | 2                                           |
| Shoulder, elbow and wrist scores | 11                                          |
| Neck, trunk and legs score       | 8                                           |
| RULA final score                 | 7                                           |
| Interpretation                   | Very high risk requires immediate response. |

The RULA score reinforces the focus on the upper extremities previously seen in the NBM results. The right wrist, right upper arm, right forearm, and right hand were the areas with the highest complaint rates. Although the NBM and RULA measure different aspects, both descriptively demonstrate that the upper extremities are a critical component in evaluating plug welding activities. The relatively high arm position, raised shoulders, and wrist movement when aiming the welding torch cause several body parts to operate far from a neutral position.

This result is in line with the research of Pratama et al.[3]and Ayutatila and Islamic[4]who obtained a high level of RULA risk in welding activities. Ahmad et al.[13]also reported a RULA score of 6 for the raw material welding activity and recommended investigation and changes to the working conditions. For the AC technicians, Pratama, Fahnury, and Rizqi[5]Achieving a RULA score of up to 7 for certain activities. This comparison demonstrates that upper limb risks can arise in various jobs where postures are far from neutral or when the activity is static and repetitive. Differences in job types prevent scores between studies from being used for direct comparisons of severity.

### 3.4 Integration of NBM, REBA, and RULA Results

NBM, REBA, and RULA provide information from different perspectives. NBM describes the musculoskeletal complaints experienced by seven operators, while REBA and RULA provide an overview of postural risks based on Operator 1's documentation. NBM results indicate dominant complaints in the right

wrist, right upper arm, right forearm, right hand, right shoulder, and waist. Meanwhile, REBA produces a score of 11 and RULA produces a score of 7.

**Table 5.**Ergonomic Assessment Results Summary

| Method | Subject       | Results | Interpretation                              |
|--------|---------------|---------|---------------------------------------------|
| NBM    | Operators 1–7 | 50–79   | Medium–high                                 |
| REBA   | Operator 1    | 11      | Very high risk requires immediate response. |
| RULA   | Operator 1    | 7       | Very high risk requires immediate response. |

Descriptively, the pattern of complaints in the upper limbs and waist in the NBM is consistent with the body parts that receive postural demands in the REBA and RULA assessments. However, this agreement cannot be used to state a statistical relationship or cause-and-effect because the subject coverage of the three methods is different. The NBM was applied to seven operators, while REBA and RULA only describe the postural condition of Operator 1. This limit of interpretation is important so that the results of the three methods are not treated as if they came from the same observation group.

The approach of using several methods is in line with Purwanto et al.[6], which integrates RULA, REBA, and OWAS to obtain a broader picture of ergonomic risks and support the determination of workstation interventions. The study shows that the use of multiple methods can capture postural risk characteristics from different assessment angles. Gifari and Ismiyah[11]also used NBM together with RULA to read subjective complaints and postural risk levels simultaneously.

In this study, the integration of the three methods was not intended to produce a new ergonomic index. NBM was used to describe operator complaints, REBA to evaluate overall body posture, and RULA provided more detailed attention to the upper limbs. These three results were then interpreted in conjunction with actual work conditions as a basis for determining the direction of ergonomic improvements.

### 3.5 Ergonomic Improvement Proposals

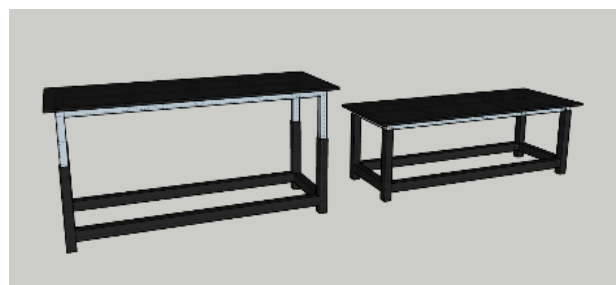
Based on the results of NBM, REBA, RULA, and the actual conditions of plug welding activities, improvements were directed at three main aspects: operator position relative to the welding point, equipment load on the upper limbs, and exposure to static postures and repetitive movements. The formulated proposals included an adjustable foot platform, cable hanger, and active rest.

**Table 6.**Ergonomic Improvement Proposals

| Findings                                           | Proposal                        | Objective                                          |
|----------------------------------------------------|---------------------------------|----------------------------------------------------|
| Low work area position and bent torso              | <i>Adjustable foot platform</i> | Adjust the operator's position to the welding area |
| The cable and welding torch load is around 5–10 kg | <i>Cable hanger</i>             | Helps support the load of equipment                |
| Static postures and repetitive activities          | <i>Active rest</i>              | Providing a chance for recovery                    |

### 3.6 Adjustable Foot Platform

*Adjustable foot platform* proposed to help adjust the operator's position to low welding points. Based on the D5 anthropometric data used in the study, the design has a height range of 329–375 mm with an adjustable mechanism.



**Fig. 6.**Adjustable Foot Platform Design

The height adjustment is aimed at reducing the need for the operator to maintain a bent torso position when reaching areas.

The facility adjustment approach based on anthropometric characteristics was also carried out by Sundari et al.[8]in designing work facilities after identifying complaints through NBM and posture risks with REBA.

Gifari and Ismiyah[11] showed that postural improvement accompanied by workbench height adjustment in the context of production work reduced RULA scores from 5–6 to 4. These findings were not used to predict the magnitude of risk reduction in plug welding activities, but support that facility height adjustment is one relevant intervention direction to evaluate.

### 3.7 Cable hanger

*Cable hanger* A proposed tool to support cables and welding torches weighing approximately 5–10 kg allows operators to avoid having to fully support the equipment using their upper limbs during the process. This proposal is based on the high incidence of wrist, arm, and shoulder complaints, as well as RULA results indicating the need for immediate change.

The use of assistive devices is also relevant to the direction of improvement proposed by Ahmad et al.[13], which recommends facilities or equipment designs to support welding activities after identifying posture risks to operators.

### 3.8 Active Rest

*Active rest* aimed at providing recovery opportunities through periodic stretching after the operator maintains a certain posture or performs the same movement repeatedly.

This proposal serves as an administrative approach that complements technical interventions such as adjustable foot platforms and cable hangers. Thus, improvements are directed not only at work facilities but also at managing exposure during the plug welding process.

Putra and Khatamy[12] In the context of catwalk welding, it also shows that high ergonomic risks require interventions to address workstation conditions. Meanwhile, Purwanto et al.[6] showed that adjusting desk height, changing material position, and using assistive devices can be part of an ergonomic intervention once postural risks have been identified. This supports the approach that ergonomic assessment results should be translated into improvements appropriate to the identified source of work demands.

## IV. CONCLUSION

Based on the results of research on the plug welding activity of rear wheel hub components in the welding division of PT SSC Works Surabaya, it can be concluded that all seven operators experienced musculoskeletal complaints based on the Nordic Body Map (NBM) results. The total NBM score was in the range of 50–79, with two operators obtaining a score of 79 which is included in the high category, while the other five operators were in the moderate category. The most dominant complaint was found in the right wrist with a total score of 27, followed by the right upper arm, right forearm, and right hand which each obtained a score of 25, as well as the right shoulder and waist with a score of 23.

Posture assessment of Operator 1 indicated that the plug welding activity posed a high ergonomic risk. The REBA result obtained a final score of 11, which is categorized as very high risk and requires immediate action. Meanwhile, the RULA result obtained a final score of 7, indicating the need for immediate investigation and change. Both results indicate that body and upper limb position during the welding process requires attention to improve working conditions.

Based on the findings of musculoskeletal complaints and postural risks, the proposed ergonomic improvements include an adjustable foot platform, cable hanger, and active rest. The adjustable foot platform was designed based on D5 anthropometric data with an adjustable height mechanism, while the cable hanger is intended to help support the load of cables and welding torches. The application of active rest is aimed at reducing exposure to static and repetitive activities. Overall, the research results can be the basis for improving working conditions in plug welding activities.

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