

Rapid Upper Limb Assessment (RULA) for Ergonomic Decision Making in Welding Postures

Mohammad Khalid Bin Wahid* and Mohd Azlan bin Mohamed

Faculty of Industrial and Manufacturing Technology and Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding Author

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ABSTRACT

Awkward welding postures were commonly associated with high ergonomic risk, but changes in Rapid Upper Limb Assessment (RULA) scores could also have reflected observer variability. This experimental study assessed whether RULA improvements after ergonomic intervention exceeded observed scoring variability. Sixteen welding conditions, including flat, horizontal, vertical, overhead, fixed-pipe, 45°-pipe, and site-constrained tasks, were evaluated before and after interventions involving work-height adjustment, workpiece rotation, arm support, ergonomic seating, and stable platforms. Observer variability was quantified from 40 RULA assessments of five reference postures. The mean RULA score decreased from 6.56 ± 1.03 to 3.88 ± 1.26 , representing a 40.9% reduction. Ergonomic risk decreased in 15 of 16 conditions, and the number of maximum RULA scores of 7 decreased from 12 to zero. Exact observer agreement was 60.0%, with a mean absolute error of 0.575 and a 90th-percentile error of 2 points. These findings indicated that RULA provided stronger evidence of ergonomic improvement when score reductions exceeded observer-related variability.

Keywords: RULA; welding ergonomics; awkward posture; workstation redesign; musculoskeletal risk

INTRODUCTION

Welding often requires awkward postures because the weld location and orientation limit neutral body positioning. Overhead, vertical, pipe, and constrained welding commonly involve arm elevation, neck extension, trunk rotation, kneeling, or squatting. Previous studies reported high ergonomic risk among welders, with RULA scores commonly ranging from 5 to 7 [2,7]. Ergonomic interventions reduced this risk for example, hand support reduced a RULA score from 7 to 3 [3]. Crouching, kneeling, and prolonged work above shoulder level have also been associated with back and shoulder pain [10]. The Rapid Upper Limb Assessment (RULA) is widely used to evaluate working posture because it is rapid and practical. However, its final score depends on observer interpretation of joint angles, muscle use, body support, force, and posture selection [1]. Recent studies have shown that RULA results may vary with assessment method and working conditions [5,9]. In welding, protective equipment, arc light, tools, cables, and restricted spaces may further affect posture observation. This variability is important when evaluating ergonomic interventions. A large reduction in RULA score is more convincing than a small one point change that may fall within observer related scoring variation. Therefore, this experimental study assessed 16 welding conditions before and after engineering controls and evaluated scoring variability using 40 RULA assessments of five reference postures. The study aimed to determine whether observed RULA improvements were sufficiently large to exceed observer-related variability and provide reliable evidence of ergonomic improvement.

MATERIALS AND METHODS

An experimental pre and post design was used to evaluate ergonomic improvements in welding postures using the Rapid Upper Limb Assessment (RULA). Data were collected from welders in Technical and

Vocational Education and Training (TVET) settings performing 16 welding conditions, including flat, horizontal, vertical, overhead, fixed pipe, 45° pipe, seated, and constrained welding tasks. Representative postures involving forward reach, arm elevation, kneeling, squatting, trunk flexion, trunk rotation, and overhead work were evaluated using the RULA procedure shown in Figure 1, in which arm and wrist postures were scored first, followed by muscle use and force or load adjustments, then neck, trunk, and leg postures were assessed before deriving the final RULA score from 1 to 7. Engineering interventions included work height adjustment, workpiece repositioning or rotation, arm support, ergonomic seating, pipe supports, adjustable positioners, and stable work platforms. Each condition was reassessed using the same RULA procedure after intervention, and score changes were used to quantify ergonomic improvement. Observer related variability was independently evaluated using 40 RULA assessments of five reference welding postures, with eight assessments per posture. Observer scores were compared with reference scores using exact agreement, mean absolute error (MAE), root mean square error (RMSE), and risk underestimation. The main outcomes were pre and post intervention RULA scores, absolute and percentage score reductions, and changes in ergonomic risk classification.

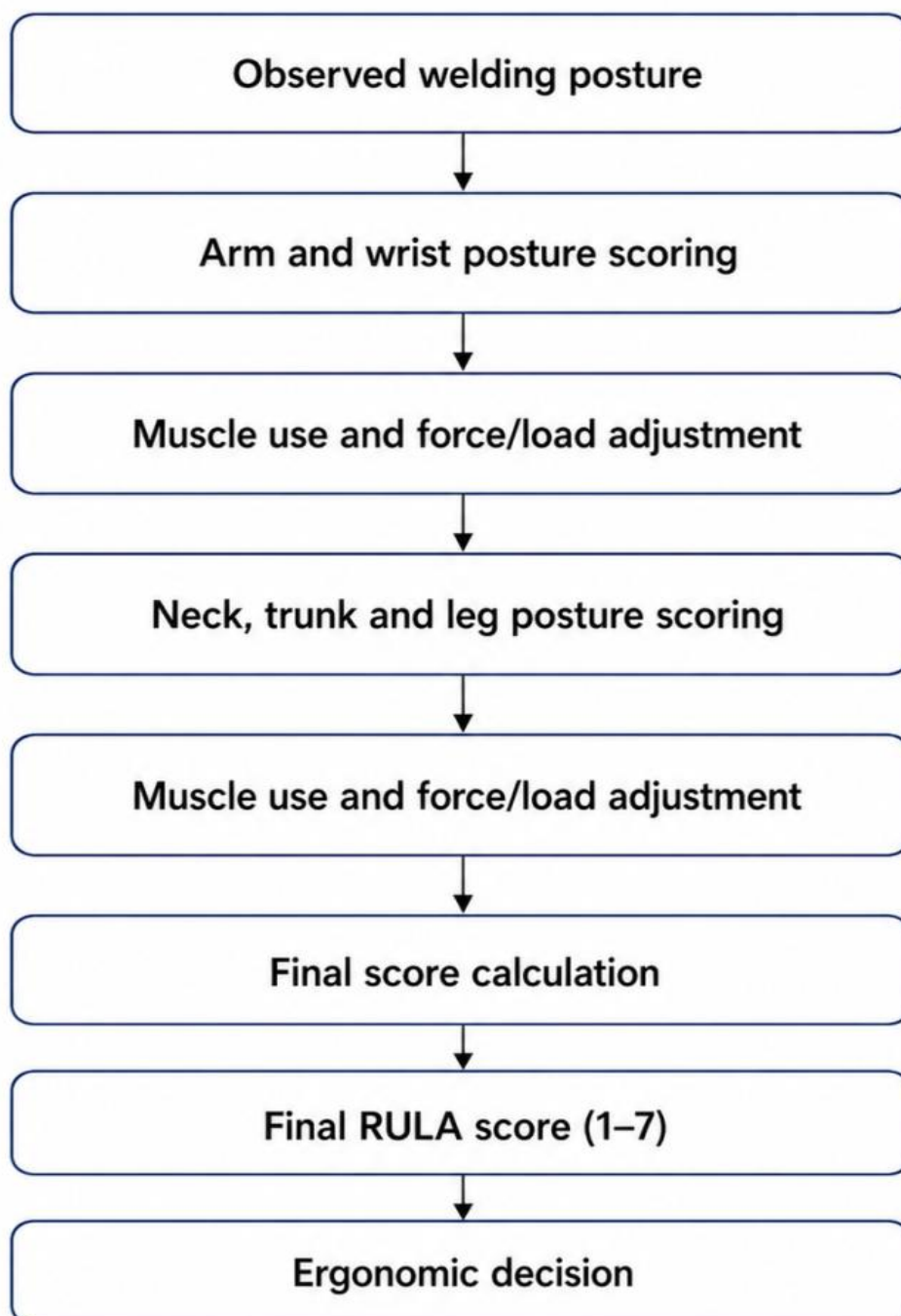


Figure 1. RULA assessment workflow for welding posture evaluation.

RESULTS AND DISCUSSIONS

Baseline postural risk across welding scenarios

Baseline assessment showed that most welding conditions involved high postural risk. The mean RULA score was 6.56 ± 1.03 , with a median of 7. Twelve of the 16 conditions (75.0%) recorded the maximum RULA score of 7, three recorded scores between 5 and 6, and one recorded a score between 3 and 4. The highest scores were observed during floor level squatting, elevated arm vertical welding, overhead welding, fixed pipe work involving overhead reach or pronounced trunk flexion, half kneeling with trunk rotation, and restricted site work. These findings indicated that limited access to the weld joint frequently required welders to adopt constrained body positions, resulting in substantial postural loading.

Effect of engineering controls

Following the engineering interventions, the mean RULA score decreased from 6.56 ± 1.03 to 3.88 ± 1.26 , while the median decreased from 7 to 3. The mean reduction was 2.69 points, corresponding to a 40.9% improvement from baseline. Fifteen of the 16 welding conditions showed lower RULA scores after intervention. As shown in Figure 2, the paired scores demonstrated a clear reduction across most welding conditions. The magnitude of improvement varied among the welding conditions. Seven conditions showed a four point reduction, two showed a three point reduction, three showed a two point reduction, three showed a one point reduction, and one condition remained unchanged. The largest improvements occurred when the engineering controls substantially changed the working geometry, particularly by raising low-level work, repositioning or rotating the workpiece, and using adjustable-height positioners. Smaller improvements were observed when the intervention improved body support but did not fully remove the original postural constraint, such as overhead fixed pipe work and restricted site conditions. As illustrated in Figure 3, the interventions shifted most welding conditions from high RULA scores toward lower score ranges, indicated an overall reduction in postural risk.

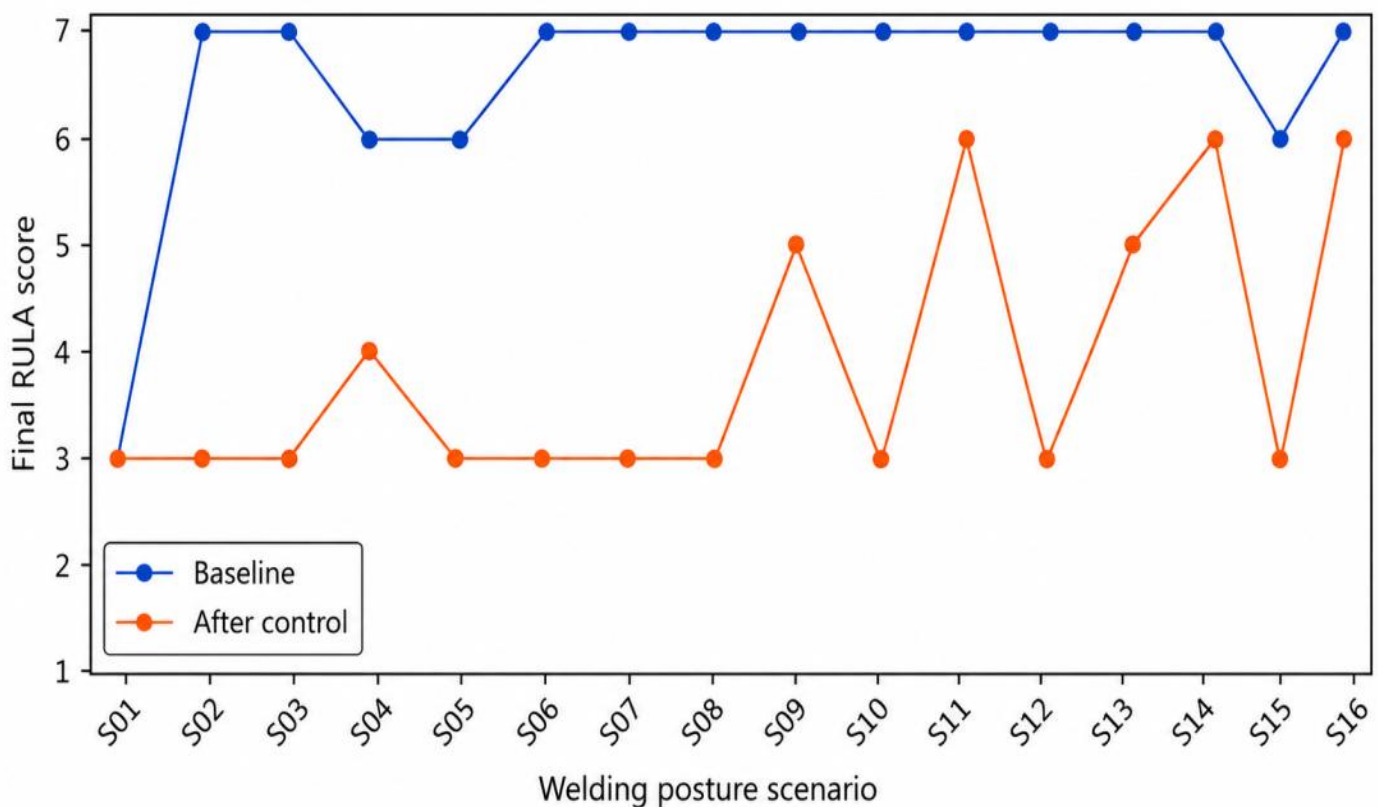


Figure 2. Paired RULA scores for the 16 welding conditions before and after engineering interventions.

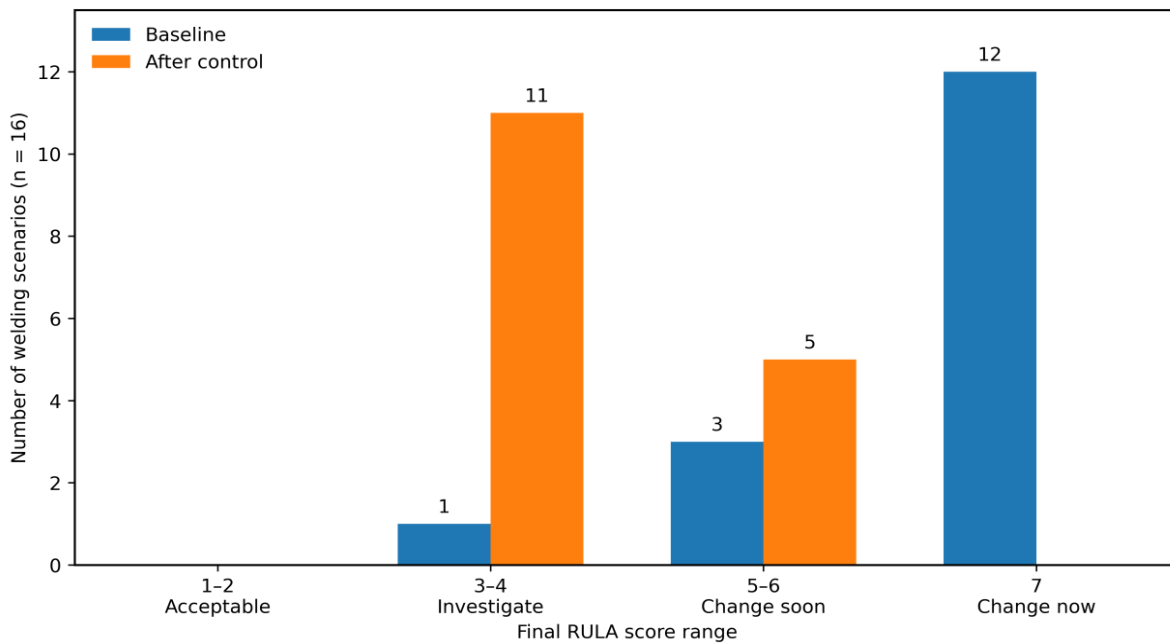


Figure 3. Distribution of RULA scores before and after engineering interventions.

Among the 40 welder assessments, 60.0% produced the same final RULA score as the reference assessment. Figure 4 showed that scoring differences were greatest for arm muscle use, trunk, neck, and upper-arm posture. In contrast, force/load and leg assessments showed smaller differences between observers. This indicated that body regions requiring greater visual judgement were more difficult to assess consistently, particularly during welding where helmets, limited visibility, and restricted working positions could obstruct the view. The engineering interventions also produced clear improvements in welding posture. Raising low-level work, repositioning or rotating the workpiece, and using adjustable positioners reduced RULA scores by up to four points. Similar improvements were reported in previous welding studies, where hand support reduced RULA from 7 to 3 [3], while workstation modification reduced the mean score from 5.91 to 2.93 [7]. Tasik et al. [14] also found that adjustable workstation design improved welding posture more effectively than minor dimensional changes. Overall, the findings showed that RULA was useful for evaluating welding posture, although some components were more dependent on observer judgement than others. The strongest ergonomic improvements occurred when lower RULA scores were supported by clear physical changes to the workstation or welding task.

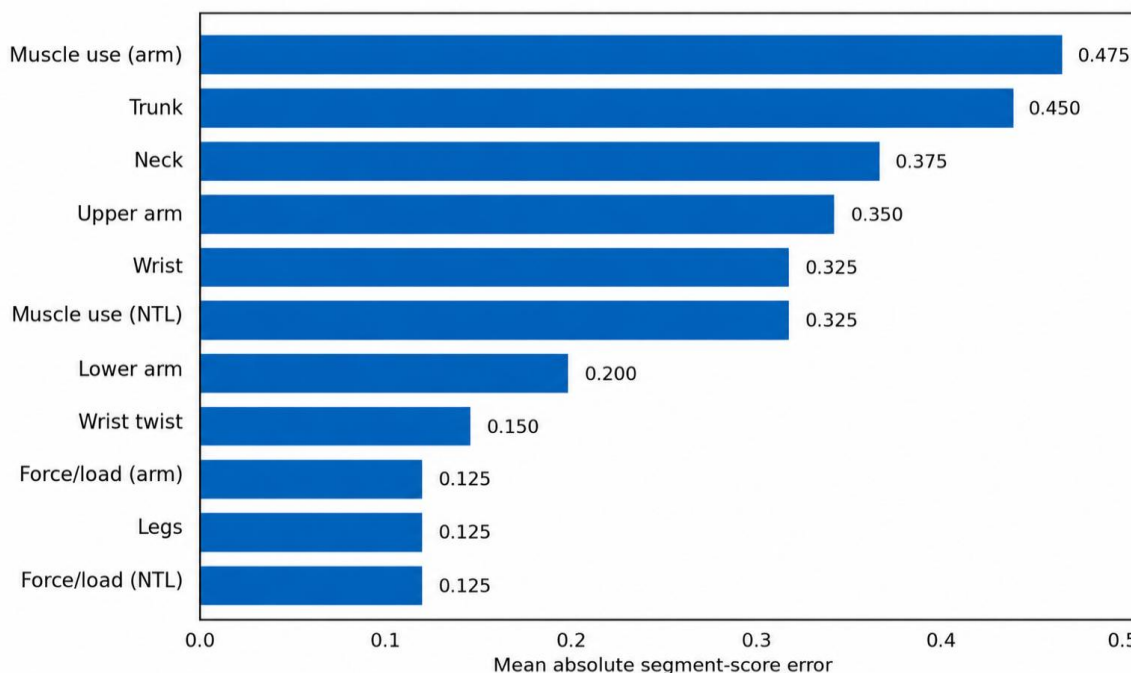


Figure 4. Mean absolute error of individual RULA components across observer assessments.

CONCLUSION

This experimental study demonstrated that engineering interventions effectively improved welding postures, reducing the mean RULA score from 6.56 to 3.88. Most welding conditions showed a clear reduction in postural risk after changes to work height, workpiece position, body support, and working platform design. The observer assessment also showed that RULA scoring was influenced by variation in the interpretation of specific body segments, particularly the arm, trunk, and neck. The findings indicated that RULA was useful for evaluating ergonomic improvements when it was applied consistently before and after intervention. Larger reductions in RULA score were associated with more substantial changes to the working geometry, while smaller reductions generally occurred when the original postural constraint remained partly unchanged. This highlights the importance of addressing the physical cause of awkward posture rather than relying only on posture correction or worker instruction. Overall, RULA provided a practical method for identifying high-risk welding postures and verifying the effectiveness of engineering controls. Its value was strengthened when assessments were supported by consistent scoring procedures and clear observation of the working posture. Effective ergonomic improvement in welding should therefore focus on redesigning the task and workstation to reduce awkward body positions and provide a measurable reduction in postural risk.

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APPENDIX A: WELDING SCENARIO AND CONTROL DEFINITIONS

Scenario	Welding condition	Baseline posture / constraint	Engineering control
S01	1G flat	Standing upright at an adjustable bench; reference condition.	No intervention (reference condition).
S02	1G flat	Low bench requiring approximately 20–60° trunk flexion.	Raise bench to approximately elbow height.
S03	1G flat	Floor-level welding in a squatting posture.	Lift the workpiece onto a bench.
S04	2G horizontal	Standing with excessive upper-arm abduction.	Reposition the workpiece to reduce arm abduction.
S05	2G horizontal	Kneeling with knee support during welding.	Provide an ergonomic welding stool.
S06	3G vertical	Elevated shoulder with sustained raised-arm posture.	Use a positioner to rotate the joint toward the 1G position.
S07	3G vertical	Kneeling posture during the lower welding run.	Use an adjustable-height positioner.
S08	4G overhead	Arm above shoulder level with neck extension.	Rotate the assembly toward the 1G position using a turntable.
S09	4G overhead	Kneeling beneath the assembly with sustained neck extension.	Raise the assembly on trestles and perform the task in a seated posture.
S10	5G fixed pipe	Half-kneeling at the 3 o'clock pipe position.	Use a pipe rotator to move the task toward a 1G working position.
S11	5G fixed pipe	Squatting at the 6 o'clock position with overhead reach.	Raise the pipe to approximately chest height.
S12	5G fixed pipe	Standing at the 12 o'clock position with trunk flexion >60°.	Raise the pipe to approximately chest height.
S13	6G pipe at 45°	Half-kneeling with trunk rotation.	Use a pipe rotator together with an adjustable seat.
S14	6G pipe at 45°	Squatting with the working arm crossing the body midline.	Use a pipe rotator together with an adjustable seat.
S15	1G plate	Seated bench welding without arm support.	Provide an adjustable arm rest.
S16	2G/3G site	Standing on a scaffold with restricted and unstable footing.	Provide a stable work platform and work rest.