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Evaluation of Workers' Working Postures based on RULA and MCDM: An Application to a SME Producing Kitchenware in Indonesia

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Abstrak

Saat ini, upaya untuk meningkatkan budaya keselamatan dan kesehatan kerja di perusahaan semakin meningkat termasuk perhatian terhadap postur kerja pekerja. Namun, implementasi ini cenderung sangat kurang terutama di perusahaan yang berskala kecil dan menengah (UMKM). Penelitian ini bertujuan untuk memperkenalkan kerangka evaluasi postur kerja pekerja dengan memperhatikan faktor ergonomi dan tingkat pengaruh aktivitas. Di dalam studi ini, model evaluasi diterapkan pada sebuah UMKM yang memproduksi peralatan dapur dengan menggunakan metode *rapid upper limb assessment* (RULA) dan dikombinasikan dengan *multi criteria decision-making* (MCDM). Terdapat lima kriteria yang diidentifikasi yaitu skor RULA (C_1), tingkat pengaruh aktivitas (C_2), durasi pekerjaan (C_3), kondisi lingkungan stasiun kerja (C_4), dan alat penunjang pekerjaan (C_5) yang digunakan untuk mengevaluasi lima postur kerja di lantai produksi. Hasil penelitian ini menunjukkan bahwa berdasarkan skor RULA, kelima postur yang dinilai menunjukkan tingkat risiko yang tinggi. Selain itu, dengan memperhatikan kelima faktor tersebut, postur pada aktivitas merakit (postur 3) memiliki tingkat risiko tertinggi yang memerlukan aksi koreksi segera. Penelitian ini sangat aplikatif karena evaluasi postur kerja dinilai dengan mempertimbangkan faktor ergonomis dan tingkat pengaruh aktivitas.

Keywords:
Work posture;
SME;
RULA;
MCDM

Abstract

Currently, it is obvious that occupational health and safety culture in companies is on the rise including a focus on workers' working postures. However, the implementation of these initiatives tends to be notably deficient, particularly in small and medium-sized enterprises (SMEs). This research aims to introduce a framework for evaluating workers' working postures taking into account ergonomic factors and other influential factors. In this study, the developed

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evaluation model was applied to an SME producing kitchenware situated in Indonesia using rapid upper limb assessment (RULA), and the method was combined with multi criteria decision-making (MCDM). There were five criteria identified, namely RULA score (C_1), the activity's level of importance (C_2), duration (C_3), work station environmental condition (C_4), and supportive equipment (C_5). These five criteria were considered to evaluate five working postures on the production floor. The result indicated that based on the RULA score, five postures were categorized as high risk. Besides, by considering the criteria, working posture in assembly activity (posture 3) has the highest risk level which requires immediate corrective action. This research is applicable as the evaluation of work posture is assessed by considering ergonomic factors and the level of importance for each activity.

1. INTRODUCTION

In today's risky business activity, it becomes a priority that manufacturers concern on occupational health and safety. A safe and healthy work environment can be achieved by creating ergonomic systems and work environments including the evaluation of work postures representing method design (Kurnianto & Andrian, 2020;Anggraini et al., 2022). This becomes critical today as the risky work postures bring injuries to employees, and further it may hinder the continuity of production process (Nova & Hariastuti, 2022;Komatina et al., 2021). The risk is increasingly significant in small and medium-sized enterprises (SMEs) where concern on work postures is still lacking. Cahyanto & Nugraha (2023) mentioned that SMEs generally focus on product development and often overlook other operational aspects such as work procedures, standardized equipment, and basic job requirements. Accordingly, this study aims to evaluate work postures, especially in small and medium-sized manufacturers.

Some past papers have conducted studies on ergonomic working posture evaluation in small-medium enterprises (SMEs). Most papers presented the rapid upper limb assessment (RULA) method as the main tool applied to various types of industries, such as food industry, furniture, crafts, and fashion (Mahmood et al., 2019;Rahma & Faiz, 2019;Utami & Nugroho, 2023;Primasari & Efendi, 2022;Salsabila & Rosyada, n.d.). Utami & Nugroho (2023b) utilized the RULA method to investigate the possible risks associated with the body postures of workers in the food industry. With the same purpose, Rahma & Faiz (2019b) employed the method in the craft industry. Primasari & Efendi (2022) proposed the RULA method to formulate prevention action as well as ergonomic equipment design for furniture operators. In addition, Salsabila & Rosyada (n.d.) designed a work chair in the fashion industry. These researchers have also combined the RULA method with rapid entire body assessment (REBA).

Although the combination of RULA and REBA has often been used to assess ergonomic working postures, the former method is also compatible when integrated with several other methods, such as ovako work analysis system (OWAS), objective matrix (OMAX), nordic body map (NBM), quick exposure check (QEC), and even other quantitative methods including multi-criteria decision making (MCDM). Suman et al. (2020) and Khamidah et al. (2022) developed RULA – OWAS to analyze the level of risk caused by risky body postures. Mukhtar & Mufarich (2019) integrated the method with OMAX to measure work productivity. Adiyanto et al. (2022) applied RULA and NBM to determine the comfort level of workers, while Rahma & Faiz (2019b) and Sri Mariawati et al. (n.d.) developed a RULA – QEC to identify parts of body at risk of injury and provide improved designs to reduce risks. An ergonomic posture evaluation with a hybrid RULA – MCDM has also been carried out by previous researchers such as (Mukhtar & Mufarich, 2019) who applied analytic hierarchy process (AHP). In the study, RULA was selected to determine the chair design for operators, while AHP was used to compute the scores towards the modified chair designs.

It is obvious that the MCDM application has been widely used to address various issues; however, the technique developed for dealing with ergonomic cases is still very limited. Accordingly, in this study the MCDM is proposed to resolve ergonomic posture issues combined with RULA in a small-medium sized manufacturer located in Indonesia. The RULA method is selected to assess and analyze the upper body postures of workers, while the AHP – one of the MCDM methods – is utilized to prioritize the risky posture that requires immediate correction considering various criteria. In this case, MCDM is able to make an effective solution as it avoids some confusing critical factors through criteria weight computation (Eraslan et al., 2020). This research, in practical terms, presents more appropriate corrective actions towards risky work postures in the company. Theoretically, the combination of RULA and MCDM conducted in this study may extend the literature that can be further developed in addressing human factor issues.

2. METHOD

There are two main stages taken in this study, namely body posture assessment using the RULA method, and ranking the work posture risk using the AHP method. First, work postures are identified based on observations specifically conducted on the production floor.

Table 1. The RULA scores

Score	Description
1-2	Low risk level, workers are in a normal and safe condition
3-4	Moderate risk level, further investigation and changes are needed in the near future
5-6	High risk level, further investigation and additional changes are necessary to prevent injuries in the near future
7+	Critical risk level, immediate investigation is required to prevent injuries

The RULA method includes body posture diagrams and three score tables, so the assessment of body posture, especially the upper body, can determine its risk level category (Praditya & Ardiansyah Ekoanindiyo, 2023). Table 1 describes the RULA risk levels (Ridwan Malik et al., 2021). Further risk assessment is conducted using the AHP method taking into account the considered factors including the RULA scores. The AHP calculation procedure follows (Susanti et al., 2023). In the AHP stages, the decision-makers (DMs) are involved in first identifying the factors necessary to analyze the work posture risk. Then, DMs will assign paired comparison scores between criteria based on the Saaty's scale of 1 to 9. To obtain the criteria weights, equation (1) is applied, where the total weight of all criteria will be 1.

$$\text{Weight of } i = w_i = \frac{\sum_{j=1}^{n} w_{ij}}{n} \quad (1)$$

$$w_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (2)$$

To ensure that the obtained weights are correct, the consistency test is calculated using equations (3) – (5). When the CR value is less than or equal to 0.10, then the weights are reliable and consistent. As this study involves three DMs, the weighted geometric mean method (WGMM) is applied to aggregate these different preferences using equation (6) (Ossadnik et al., 2016).

$$R = \frac{CI}{RI} = \frac{\text{Consistency Index}}{\text{Random Consistency of A}} \quad (3)$$

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

$$RI = \frac{1.98(n-2)}{n} \quad (5)$$

$$A^{WGMM}(i,j) = \prod_{r}^{R} = 1 (a_{i,j}^{r})^{w^r} \quad (6)$$

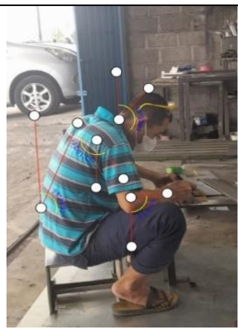
Where w^r is a weight of r. Finally, the ranking of alternatives is also completed using the AHP method which then determines the riskiest posture taking into account the factors identified. Work postures with the highest risk value need to be corrected immediately.

3. RESULT AND DISCUSSION

3.1. Work Posture Identification

Firstly, risky working postures are identified based on observation. It can be seen from Table 2 that there are five risky working postures identified on the production floor.

Table 2. Some potential work-related disorders on production floor

Work Posture 1	Work Posture 2	Work Posture 3	Work Posture 4	Work Posture 5
				
The finishing process done in a standing position	Installing electricity in a standing and bending position	Assembly process in a squatting position	Welding process in a squatting position	Measurement process in a bent position

Posture 1 is the posture when workers are involved in the finishing process. The finishing work is done in a standing position with the body leaning to the side, repeatedly and for a considerable duration. Posture 2 is the posture when workers install electrical wiring by standing with a bent body. Posture 3 is the posture when workers perform assembly process which are done in a squatting position. Posture 4 is the posture when workers engage in welding processes performed in a squatting position with the head leaning forward and heels raised. Posture 4 is exacerbated by minimal use of personal protective equipment. Posture 5 is when workers measure bending tolerance done in a squatting position and on a lower table, requiring workers to bend for an extended period of time.

3.2. Work posture assessment using RULA

The second stage is to calculate the RULA score to determine the risk level of upper working posture of the identified postures. The result is shown in table 3.

Table 3. The assessment of each posture using RULA

Steps	Work Postur 1 Score	Work Postur 2 Score	Work Postur 3 Score	Work Postur 4 Score	Work Postur 5 Score
A. Arm and wrist score					
1. Upper Arm	+2	+2	+2; +1	+2	+2
2. Lower Arm	+1; +1	+1	+2; +1	+2	+1
3. Wrist	+3	+3	+3; +1	+3	+3
4. Wrist Twist	+1	+2	+2	+1	+1
5. Postur Score A	3	4	5	3	3
6. Muscle Use	0	0	0	0	0
7. Force/Load	+1	+1	+1	+1	+1
8. Wrist&Arm Score	4	5	6	4	4
B. Neck, trunk, and leg score					
9. Neck	+3	+3	+3	+3	+3
10. Trunk	+3	+3	+2	+2	+3
11. Legs	+1	+1	+2	+2	+2
12. Postur Score B	4	4	4	4	5
13. Muscle Use	+1	+1	+1	+1	+1
14. Force/Load	0	0	0	0	0
15. Neck, Trunk, Leg Score	5	5	5	5	6
16. RULA Score	5	6	6	5	6

Based on the table above, the RULA scores for these five postures ranged from 5 to 6 indicating that the working postures in all production areas are risky and require immediate changes. This condition is exacerbated by inadequate equipment and work facilities and is also performed for very long durations. For example, workers performing assembly processes (Posture 3) have to squat for nearly eight hours. Additionally, in Posture 5, workers perform measurements in a bent-over body position as the measuring table is low and immovable.

3.3. Work posture evaluation using MCDM

Although all five measured working postures assessed using RULA show high-risk values, it is crucial to prioritize the working postures that need immediate correction. In this study, the AHP is applied to make decisions on prioritizing the posture improvements more effective and efficient. Initially, three DMs were involved in identifying the criteria. Table 4 shows the five identified criteria and the indicators with a range of 1 – 5 used to rate each posture. There are five identified criteria, namely RULA score (C_1), activity's level of importance (C_2), duration (C_3), workstation environmental condition (C_4), dan supportive equipment (C_5). These five criteria indicate that for a comprehensive decision-making process, the DMs should not only consider the RULA score but also other factors, and thus, decision making will be more realistic since an activity with a high RULA score may not necessarily guarantee a significant positive result when improved.

Table 4. Identified criteria and rating conversion

Code	Criteria	Definition	Rating conversion
C_1	RULA score	Postural assessment for the upper body	1=neglible risk; 2=low risk; 3=medium risk; 4=high risk; 5=very high risk
C_2	Activity's level of importance	The level of significance of an activity towards overall process	1=unimportant; 2=considerable; 3=moderate important; 4=important; 5=crucial
C_3	Duration	The length of time required per cycle	1=<5 min/cycle; 2=5-10 min/cycle; 3=10-15 min/cycle; 4=15-30 min/cycle; 5=>30 min/cycle
C_4	Workstation environmental condition	The existing workplace condition	1=intermittent noise; 2=narrow spectrum noise 3=broad spectrum noise; 4=impulsive; 5=repetitive noise
C_5	Supportive equipment	Tools, machinery, or equipment used by workers to complete their job according to the level of complexity	1=manual; 2=low complexity; 3=moderate complexity; 4=high complexity; 5= very complex

Once five criteria and five alternatives have been identified, the hierarchical structure of decision making can be structured as follows:

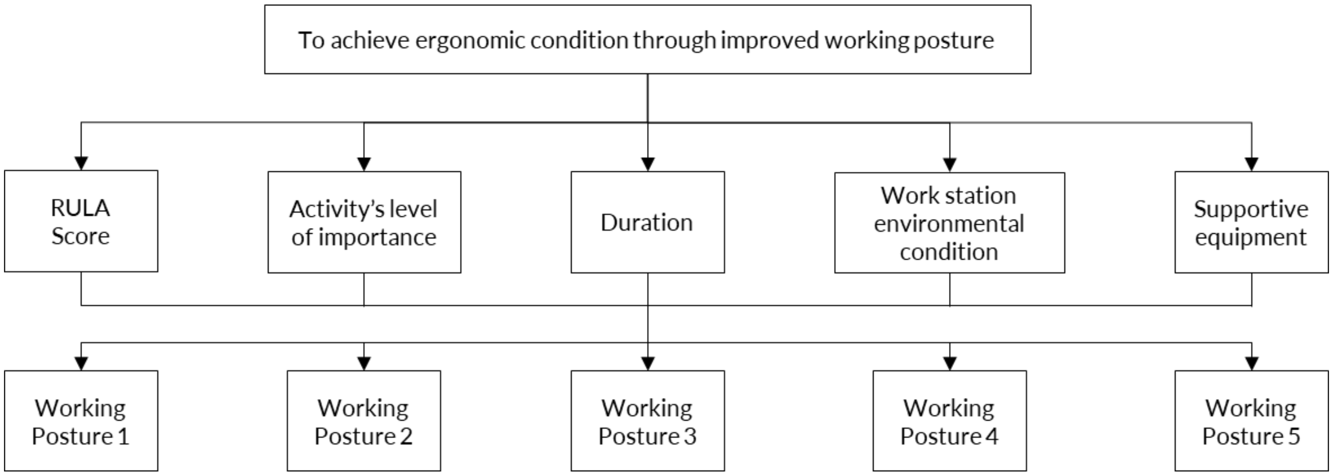


Fig. 1. The evaluation model structure

Furthermore, through a group discussion, the DMs provided preference values for pairwise comparisons between criteria, resulting in three pairwise comparisons matrices. The aggregation of the three respondents is computed using the WGMM as presented in equation (6). Table 5 and Table 6 present the weight generated by the three respondents and their aggregated weights.

Based on the table above, the aggregation weights produce the order of criteria $C_3>C_2>C_4>C_5>C_1$.Then, the consistency test yields the CI value of 0.417 and the CR value of -0.372 which is considered acceptable or consistent. After the criteria weights are obtained, the next step is to prioritize the work postures by scoring each posture based on the criteria referring to table 3. Table 6 presents the rating for each posture according to the considered criteria. Then, the posture weight is also calculated using AHP and the global weight is obtained as illustrated in Table 7 and Table 8.

It can be observed from Table 8 that the decision-making process indicates the optimal weight results as follows: Posture 1 is 0.405, Posture 2 is 0.140, Posture 3 is 0.058, Posture 4 is 0.084, and Posture 5 is 0.312. the order from the riskiest to the least risky posture is as follows: Posture 3 > Posture 4 > Posture 2 > Posture 5 > Posture 1. Accordingly, Posture 3 is declared as the riskiest working posture requiring immediate improvements. Then, based on the RULA calculation, it can be seen that Posture 3 involves a squatting position during the assembly process. The RULA calculation has also confirmed the AHP result that Posture 3 has the RULA score of 6 which is considered relatively high.

Table 5. Preference scores of criteria comparisons from three DMs

	C_1	C_2	C_3	C_4	C_5	
C_1	1.000	0.333	0.143	0.111	0.200	DM_1
C_2	3.000	1.000	0.200	0.143	0.333	
C_3	7.000	5.000	1.000	0.333	3.000	
C_4	9.000	7.000	3.000	1.000	5.000	
C_5	5.000	3.000	0.333	0.200	1.000	
Geomean	3.936	2.036	0.491	0.254	1.000	7.718
Weight	0.510	0.264	0.064	0.033	0.130	1.000
C_1	1.000	0.200	0.250	0.333	3.000	DM_2
C_2	5.000	1.000	3.000	4.000	7.000	
C_3	4.000	0.333	1.000	3.000	5.000	
C_4	3.000	0.250	0.333	1.000	4.000	
C_5	0.333	0.143	0.200	0.250	1.000	
Geomean	1.821	0.299	0.549	1.000	3.347	7.016

Weight	0.260	0.043	0.078	0.143	0.477	1.000
C_1	1.000	0.333	0.200	5.000	3.000	DM_3
C_2	3.000	1.000	0.333	8.000	5.000	
C_3	5.000	3.000	1.000	9.000	8.000	
C_4	0.200	0.125	0.111	1.000	0.333	
C_5	0.333	0.200	0.125	3.000	1.000	
Geomean	1.000	0.478	0.247	4.043	2.091	7.860
Weight	0.127	0.061	0.031	0.514	0.266	1.000

Table 6. Aggregated weight using WGMM

	C_1	C_2	C_3	C_4	C_5	Geomean	Weight
C_1	1.000	0.327	0.211	0.301	0.673	0.426	0.123
C_2	1.530	1.000	0.641	0.720	0.897	0.913	0.264
C_3	1.327	1.052	1.000	1.089	1.299	1.146	0.332
C_4	0.549	0.300	0.286	1.000	0.730	0.510	0.148
C_5	0.544	0.297	0.231	0.561	1.000	0.462	0.134
					Σ	3.456	1.000

The risk associated with a squatting position is that it tends to be less stable compared to sitting or standing positions, increasing the risk of falling or instability while performing tasks. Squatting position can also place additional stress on joints such as the knees, ankles, and hips, potentially leading to tension and joint injury risks. Working in this position can cause discomfort and injury risks. Consequently, follow-up actions should include a well-designed working environment and adhere to ergonomic principles to reduce the risk of injuries and discomfort. Additionally, providing appropriate ergonomic equipment can help reduce strain on the body and improe workers' well-being.

Table 7. The decision matrix for each posture based on each criterion

Postures	C_1	C_2	C_3	C_4	C_5
Posture 1	5	2	2	3	2
Posture 2	6	3	3	2	3
Posture 3	6	4	5	4	5
Posture 4	5	5	4	2	4
Posture 5	6	2	2	1	2

Table 8. The obtained global weights for each postures

Postures	C_1 w = 0.123	C_2 w = 0.264	C_3 w = 0.332	C_4 w = 0.148	C_5 w = 0.134	Global Weight
Posture 1	0.063	0.070	0.167	0.069	0.036	0.405
Posture 2	0.008	0.035	0.043	0.037	0.018	0.140
Posture 3	0.004	0.017	0.011	0.021	0.005	0.058
Posture 4	0.032	0.009	0.021	0.012	0.009	0.084
Posture 5	0.016	0.133	0.088	0.007	0.067	0.312

4. CONCLUSION

This research employs the RULA method and MCDM, specifically AHP, for evaluating the riskiest body posture. Despite the posture assessment, there are still other factors to be considered. In this study, in addition to RULA score, there are four criteria, namely RULA score (C_1), activity's level of importance (C_2), duration (C_3), workstation environmental condition (C_4), and supportive equipment (C_5). By considering non-ergonomic factors, the decision-making process becomes more real and comprehensive. This also reveals that although the five working postures have a high level of risk, the postures taken for the longest duration (C_3) will have a severe direct impact on the workers. Meanwhile, Posture 3 is considered as the riskiest posture since it has a critical number for almost all criteria.

Although this study has developed an MCDM-based work posture evaluation model, the recommendations have not been formulated. Further research is suggested to elaborate recommendations for each risky posture where priority improvement can also be determined using the MCDM approach. Moreover, it is clear that the combination of ergonomics and MCDM can be applied to solve some relevant issues in SMEs so that the results may be quantitatively justified.

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