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ENHANCING EFFICIENCY OF THE RULA BY INTERFERING WITH FUZZY LOGIC

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ABSTRACT

Rapid upper limb assessment (RULA) is a survey method developed for assessing the exposure to risk factors associated with musculoskeletal disorders (MSDs). Based on the results of the data collection and the process using the RULA method the work tools or workstations are redesigned in order to avoid musculoskeletal problems. However, users of this tool may be uncertain about his/her risk assessment. A new model based on Fuzzy logic is presented to eliminate the uncertainty that occurs through the risk calculation. The proposed model was verified by a real case study in a solar power plant cleaning process and showed more flexibility in the decision-making.
Keywords: *RULA, Fuzzy Logic, Efficiency, Risk Assessment*

1. INTRODUCTION

Modern industrial and commercial organizations focus on improving the level of their competitive environment in the market, especially in the global economy, through cost reduction and improving human performance and sustaining it at a high level. The decision-making method is one of the most important methods that are used to solve the problem of improving human performance and work environment risk [1, 2]. The work environment is closely related to the general safety of workers in industrial facilities. Therefore, the means of making decisions related to public safety must be improved to have more reliable results. This means that all components affecting the work environment are taken into account in the decision-making process, including the uncertainty of the data that is used in the decision analysis [3]. Recent studies cate that fuzzy logic is one of the most important tools that are used to improve the results of decision-making by introducing uncertainty as a major part of decision-making components and not neglecting it by reshoring decision-making [4].

Ergonomic risk is one of the most important topics related to the work environment and humans, which requires decisions to reduce risks [5]. Many methods are used to measure risks such as Rapid Upper Limb Assessment (RULA) [6]. However, there is a scares attention to the uncertainty of RULA.

Therefore, in this paper, we propose modifying RULA using fuzzy logic to improve results and reduce the effect of uncertainty in the results. This study will be based on introducing fuzzy logic to the method of risk assessment according to the RULA. The importance of this study comes through an improved formulation of the method interfering with the fuzzy extension in risk analysis and giving more comprehensive results, and it is possible to conduct future studies as a broader extension of the proposed modification in terms of improvement or application in different sectors.

This paper is organized as follows: Firstly, the role of decision-making in improving human performance upon results from literature was introduced. Secondly, the main definitions of the ROLA method, fuzzy logic and their applications were presented from the previous studies. While the third section will include the study methodology for formulating the method through fuzzy logic, and then the results in the fourth section. Finally, the practical application to the proposed methodology and conclusion were discussed.

2. LITERATURE REVIEW AND MAIN DEFINITIONS:

This section will focus on previous studionhin the topics related to the ROLA method and fuzzy logic in addition to the main definitions.

2.2 Rapid Upper Limb Assessment

Historically, the Rolla method was created in 1993 by Lynn McAtamney and Nigel Corlett of the University of Nottingham's Institute of Occupational Ergonomics [7]. According to the original study, the definition of the Rolla method is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported [7]. Despite the importance of the method, it included an indication that it aims to achieve the minimum levels of safety, according to the following text extracted from the study: "It is of particular assistance in fulfilling the assessment requirements of both the European Community Directive (90/270/EEC) on the minimum safety and health requirements for work with display screen equipment and the UK Guidelines on the prevention of work-related upper limb disorders" [7]. RULA was developed without the need for special equipment, in the same context, the method does not need complex assessment tools for measurement, so it facilitates the application in addition to being inexpensive, and these advantages are not available in other more complex and more expensive assessment methods, these advantages made the method later one of the most widely used methods.

Extensions of research on the Rolla method were based on topics of direct relevance to case studies within the scope of working posture, assessment, upper limb disorders, and back and neck. Therefore, the studies varied according to the work environment as a distinguishing mark between the researches, although the method is the same. For example farmers [8], the work environment that is based on the use of phones [9], manual feeding of a wood-chipper [10], rice milling [11], furniture manufacturing industry [12], pharmacy [13], an office chair user in the computer work environment [14]. The diversity of studies and cases indicates the effectiveness of the method, and the extension of the studies over a period extended for three decades also indicates the effectiveness, validity and reliability of the method.

2.2 Fuzzy Logic

Fuzzy Logic was introduced by Lotfi Zadeh in 1965 [15]. In the sixties the last decade, fuzzy logic did not receive an expansion in research, but later it became widespread and interconnected in various applied, engineering, human and natural sciences [16-18] The expansion of fuzzy logic contributed to eliminating the logic of uncertainty in other sciences. This was reflected in more reliable and more accurate results. It also contributed to the expansion of alternatives in studies that depend on assessment and decision-making [19-22].

3. METHODOLOGY

In this part of the study the general methodology for using RULA, and the modification methodology using fuzzy logic will also be explained.

3.1 General Description

RULA was developed to evaluate the exposure of individual workers to ergonomic risk factors associated with upper extremity musculoskeletal disorders (MSDs). A single-page worksheet is used to evaluate required body posture, force and repetition. Using the RULA worksheet, the evaluator assigns a score for each of the following body regions: upper arm, lower arm wrist, neck, trunk and legs. After the data for each region is collected and scored, tables on the form are then used to compile the risk factor variables, generating a single score that represents the level of MSD risk. A score of 1 indicated the best or most neutral posture and a score of 4 indicated the worst position. The final RULA score is obtained from table C and is used to predict the risk level. The grand score which is a combination of scores C and D reflects the musculoskeletal loading associated with the worker's posture. Whereas, low scores (1 or 2) indicate an acceptable risk level. Action is recommended for the higher scores (2-7): for grand scores of 3 or 4 further investigation and changes are needed. While for score 7, investigations and changes are required immediately. Below is an explanation of the stages of applying the method in detail.

3.2 Analysis Of The Main Stages

In this part, the RULA method will be explained in detail, and the purpose of the mathematical detail is to explore the positions of the non-fuzzy points in each part separately. The assessment using RULA worksheet is presented in Figure 1.

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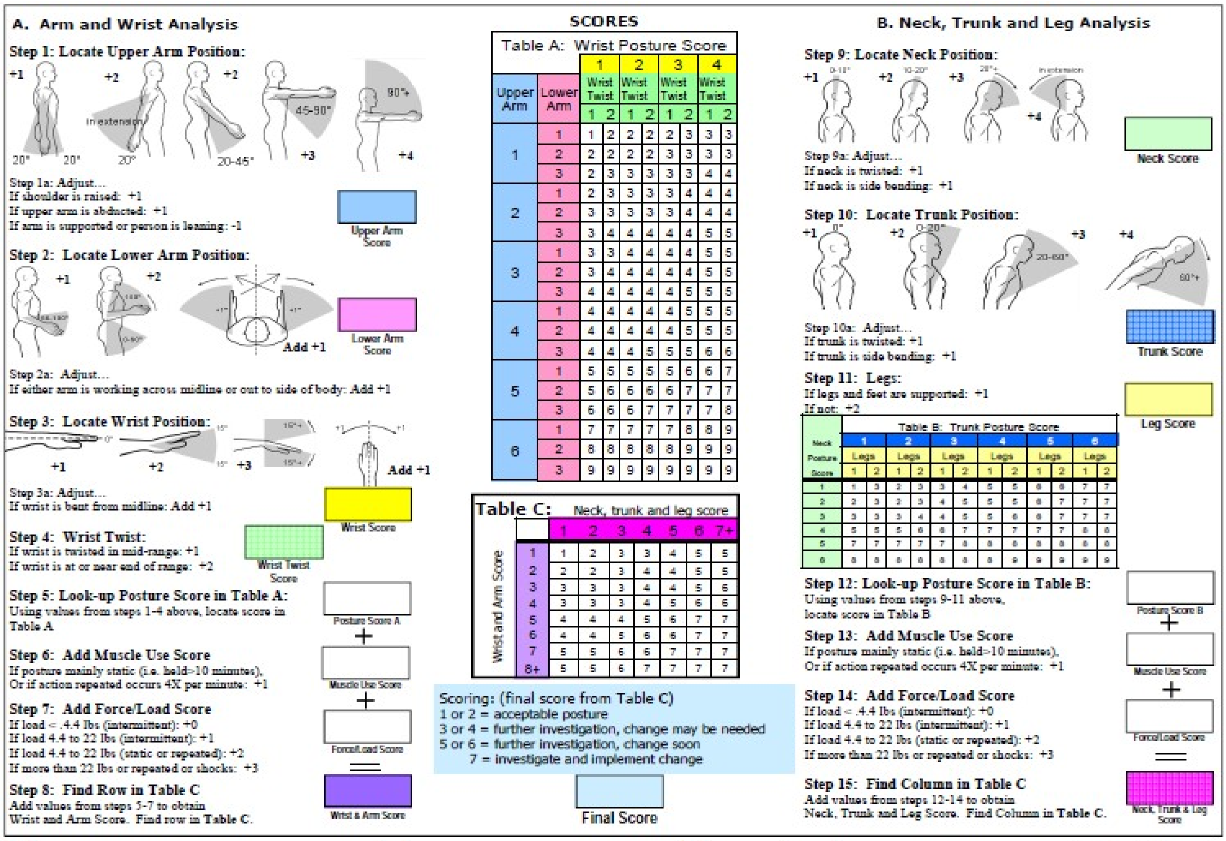

Figure 1. RULA Employer Assessment Worksheet (McAtamney& Corlett, 1993)

By reviewing the original paper of the RULA (McAtamney& Corlett, 1993), the main stages can be detailed as follows:

Stage 1: The body was divided into two groups, the first group (A) includes the upper and lower arm and wrist while the second Group (B) includes the neck, trunk and legs.

Stage 2: Estimate the movement measures for each group and represent them with numbers that represent the severity of the risk. The assessment of the movement's position included the following:

Group (A) and Group (B) include the following range of motion levels as explained in the Tables 1 untile Table 7:

Table 1. Range of motion and scores for upper arm (Group A)

Body Part	Movement	Degree	Score	Elevated Shoulder	Abducted Upper Arm	Having Arm Support	Range of Score
Upper Arm	Extension	1° – 20°	1	+1	+1	-1	0 - 3
		20° – 45°	2	+1	+1	-1	1 - 4
		45° – 90°	3	+1	+1	-1	2 - 5
		More Than90°	4	+1	+1	-1	3 - 6

Table 2. Range of Motion and Score for Lower Arm (Group A)

Body Part	Movement	Degree	Scores	Working across the midline of the body or out to the side	Range of Score
Lower Arm	Flexion	60º – 100º	1	+1	1 - 2
		Less Than 60º	2	+1	2 - 3
		More Than 100º	2	+1	2 - 3

Table 3. Range of Motion and Score for Wrist (Group A)

Body Part	Movement	Degree	Scores	If the wrist is in either radial or ulnar deviation	Range of Score
Wrist	Neutral Position	Neutral	1	+1	1 - 2
	Flexion or Extension	0º – 15º	2	+1	2 - 3
	Flexion or Extension	For 15º or More	3	+1	3 - 4

Table 4. Range of Motion and Score for Wrist twist (Group A)

Body Part	Movement	Degree	Scores	Range of Score
Wrist	Twist	Mid-Range	1	1
		Near The End of the Range	2	2

Table 5. Posture ranges and scores for neck (Group B)

Body Part	Movement	Degree	Score	If the neck is twisted	If the neck is in side-bending	Range of Score
Neck	Flexion	1º – 10º	1	+1	+1	1 - 3
		10º – 20º	2	+1	+1	2 - 4
		More than 20º	3	+1	+1	3 - 5
	Extension	Extension	4	+1	+1	4 - 6

Table 6. Posture ranges and scores for trunk (Group B)

Body Part	Movement	Degree	Score	If the trunk is twisting	If the trunk is in side-bending	Range of Score
Trunk	Sitting	90º or More	1	+1	+1	1 - 3
	Flexion	0º – 20º	2	+1	+1	2 - 4
	Flexion	20º – 60º	3	+1	+1	3 - 5
	Flexion	60º or More	4	+1	+1	4 - 6

Table 7. Posture ranges and scores for leg (Group B)

Body Part	Movement	Weight	Score	Range of Score
Leg	Sitting and Supported	Evenly Balanced	1	1
	standing and Supported	Evenly Balanced	1	1
	Legs and Feet are not Supported	Unevenly Balanced	2	2

It is clear from Table 1 until Table 7 that the range score is from 1 to 2 for Motion and Score for Wrist Twist (Table 4) and for Posture ranges and scores for leg (Table 7). Range score 1 to 3 for Motion and Score for Lower Arm Table (2). Range score 1 to 4 for Motion and Score for Wrist (Table 3). Range score 1 to 6 for the following: motion and scores for upper arm; Posture ranges and scores for neck; Posture ranges and scores for leg as indicated in Tables 1, 5 and 6. Tables 1 until 7 indicate that there is no overlap between the range of scores.

Stage 3: The muscle use scores are added to posture score group A and group B. Give a score of I if the posture is mainly static (held for longer than 10 minutes or reputed more than 4 times/min.)

Stage 4: The force or load score which is added to posture score group A and group B. Give a score according to the following Table8:

Table 8. Force or Load Score

Weight and Condition Description	Score
No resistance or less than 2kg intermittent Load or force.	0
2kg-10 kg intermittent load or force.	1
2kg-10 kg, static/repeated load or force.	2
More than 10 kg, static/repeated load or force.	3

3.2 FUZZY IN RULA

In this part of the study, the previous tables will be reformulated within a logic that takes into account the specificity of the risks spots. The logic of the presence of ambiguity in the method comes from the following observations:

1. The presence of overlap in the range of scores in the tables causes uncertainty in the result and this may cause an error in the evaluation and in the actions that can be taken after the evaluation process.

2. It is noted in the arithmetic evaluation processes that the presence of risks in a specific part of the body may vanish due to the overlapping of arithmetic operations, so the logic necessitates the existence of separation in the evaluation of risks so that each case takes a particularity.

3.3 SUGGESTED MODIFICATIONS

To neutralize this ambiguity, the proposed methodology can be used according to the following the previous tables, as follows:

Table 9. Range of Motion and Scores for Upper Arm and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1 - 3	A	1	0.166
		2	0.332
		3	0.498
1 - 4	B	1	0.166
		2	0.332
		3	0.498
		4	0.664
2 - 5	C	2	0.332
		3	0.498
		4	0.664
		5	0.833

3 - 6	D	3	0.498
		4	0.664
		5	0.833
		6	1.000

In Table 9. The red colour shows the interference with the first level, the blue colour is the interference with the second level, the green colour is the interference at the third level, and the black colour represents the interference with the fourth level.

Table 10. Range of Motion and Scores for Lower Arm and The Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1 - 2	A	1	0.333
		2	0.666
2 - 3	B	2	0.666
		3	1.000
2 - 3	C	2	0.666
		3	1.000

In Table 10. The red colour indicates the interference with the first level, the blue colour the interference in the second level, while the green colour represents the interference with the third level.

Table 11. Range of Motion and Score for Wrist and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1 - 2	A	1	0.250
		2	0.500
2 - 3	B	2	0.500
		3	0.750
3 - 4	C	3	0.750
		4	1.000

In Table 11. The red colour depicts the interference with the first level, the blue colour the interference in the second level, while the green colour represents the interference with the third level.

Table 12. Range of Motion and Score for Wrist Twist and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1	A	1	0.500
2	B	2	1.000

In Table 12. The red colour shows the interference with the first level, and the blue colour the interference in the second level, it is clear that there is no overlap between the first and second levels. In this case, there is no ambiguity in defining the risks.

Table 13. Posture Ranges and Scores for Neck and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1 - 3	A	1	0.166
		2	0.332
		3	0.498
2 - 4	B	2	0.332
		3	0.498
		4	0.664
3 - 5	C	3	0.498
		4	0.664
		5	0.833
4 - 6	D	4	0.664
		5	0.833
		6	1.000

In Table 13. The red colour shows the interference with the first level, the blue colour the interference with the second level, the green the interference at the third level, while the black colour represents the interference with the fourth level.

Table 14. Posture Ranges and Scores for Trunk and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1 - 3	A	1	0.166
		2	0.332
		3	0.498
2 - 4	B	2	0.332
		3	0.498
		4	0.664
3 - 5	C	3	0.498
		4	0.664
		5	0.833
4 - 6	C	4	0.664
		5	0.833
		6	1.000

In Table 14. The red colour shows the interference with the first level, the blue colour the interference with the second level, the green the interference at the third level, while the black colour represents the interference with the fourth level.

Table 15. Range of Motion and Score for Leg and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1	A	1	0.250
1	B	1	0.250
2	C	2	1.000

In Table 15. The red colour shows the interference with the first level, the blue colour the interference in the second level, while the green colour represents the interference with the third level.

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Table 16. The Score for Force or Load and the Risk Ratio

Range of Score	Scores Levels	Score	Risk Ratio
1	A	1	0.333
2	B	2	0.666
3	C	3	1.000

Depending on Tables 9 until 16, if we specify a measure of risk at a rate of more than 50%, this means that a high risk can be specified in the position of the upper arm, lower arm, twist, neck, trunk, leg, force and load, this means that action must be taken in this particular part.

3.4 COMBINE THE RISKS

In the case of the overall assessment of the work situation, a preliminary comparison between the risk positions must be taken into account, so that weights are given for each position.

$$\sum_{1}^{7} \text{Highest Score in All Tables} = 7$$

Through the previous methodology, the risks were divided, and the presence of overlap between the risk loci was taken into account. Within the simple calculations, it is possible to arrive at an assessment of the risks measured within a relative scale that represents the case as an integrated whole through the following equation:

$$\text{Percentage of Risk} = \sum_{1}^{7} \frac{\text{The Risk Ratio Found in Each Table}}{7}$$

4. CASE STUDY

In this part of the study, an applied study was conducted on the original Rula methodology and the proposed method. The study was conducted for one sample in the solar power plant (cleaning process), where the results were as follows:

1. RULA Results: It showed the existence of a total value of the risks due to the nature of the work of the book arranging workers. Its value: 4.

This means the need for more exploration of the sources of risks and a process of future change. This result is vague, and did not specify the exact source of the risk.

2. New Modification: It showed the existence of a total value of the risks due to the nature of the work of the book arranging workers. Its value:

$$\text{Percentage of Risk} - \sum_{1}^{7} \frac{\text{The Risk Ratio Found in Each Table}}{7} - \frac{5}{7} - 0.714$$

Where the highest values were taken in the upper arms, as well as in the trunk, neck and leg due to standing and sitting, while it was found that the weights are limited and the movement of the wrist is affected. This means that there is a need to change to avoid risks, with priority given to the movement of the trunk, leg, and neck, respectively. Where these details facilitate the process of decision-making and locating the change without the need for a process of exploration supportive of the assessment.

5. CONCLUSION

This study has presented a simple improvement on the RULA method. The modifications preserved the basic rules of the method, while the mathematical methodology of the evaluation was modified, where the logic of fuzzy has been taken into account due to the overall overlap between the risk positions. The modifications have shown a precise convergence in the assessment between the RULA method before and after the modification, In addition, the adopted amendments gave a more detailed accuracy of the value of the risks and their positions. More applications and comparisons can be made to prove the effectiveness and validity of the modifications within different working environments.

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