ERGONOMIC RISK ASSESSMENT IN CERTAIN INDUSTRIAL FIELDS USING THE QEC AND RULA METHODS

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Abstract: *In many industrial activities carried out by workers, some parts of the human body or even the body as a whole are overused to a degree that can affect the health of the workers. Established ergonomic risk assessment methods include QEC and RULA, and these methods aim to assess the risk factors that may cause workers to develop WMSDs. The purpose of this study is to evaluate the ergonomic risks related to workers' bodily postures when they work on conveyor belts. By using the QRC and RULA methods comparatively, it is possible to see which of the two tools are more suitable for evaluation in this type of activity and which of the two methods offers a more accurate diagnosis. The ERGOWORK version 2.7B software application was used for data entry and processing, which implements both methods. Based on the results obtained, conclusions and recommendations were drawn regarding the workers' workstations, and these can be materialized in the redesign of the work equipment and/or the replacement of the worker, in the execution of certain operations, by automatic machines.*

Keywords: *ergonomics, QEC, RULA, OHSS, WSDs, risk assessment*

1. INTRODUCTION

It is already known that one of the most frequent causes of occupational diseases are musculoskeletal disorders. Work-related musculoskeletal disorder (WMSD) is a term that refers to any disorder that affects muscles, nerves, the supporting bone structure of the body, tendons as a result of performing an activity [1].

In the last 10 years, there has been an increase in the number of cases of musculoskeletal disorders among workers in the industrial field. Although technology has evolved and has a high degree of human adaptability, workers are still exposed to a number of ergonomic risk factors.

The evolution of technology has eliminated or improved some work situations in which workers were affected, but on the other hand, it has increased the pace of work and physical and mental demands on workers in certain areas of the production chain, as workers it must keep up with technology and not slow down production. At the same time, the safety and health specialists tried to identify these ergonomic risk factors as accurately as possible and to evaluate them, in order to find the best improvement and control measures for these risk factors.

In this regard, various methods of ergonomic risk assessment are used internationally. Some of these methods, although using their own parameters that are different from other methods, seem to be similar. And then the question arises which method of ergonomic risk assessment is more appropriate.

In this study, we compared, using the same case study, two methods of ergonomic risk assessment that are quite widely used internationally. These two methods are QEC [2-5] and RULA [6, 7]. Both methods, The QEC (1998) and RULA (1993) methods mainly aims at the evaluation of risk factors during the activities, which have been found to have a major impact on the occurrence WMSD, such as biomechanical factors (improper body postures, repetitive movements, force exertion for lifting and carrying heavy loads, static work, bending and continuous rotations and task duration) and environmental factors (which are including temperature, psychological and organizational factors including high production demand, low control and lack of social support as well as personal factors like gender and age).

2. METHODS IN ERGONOMIC RISK ASSESSMENT IN INDUSTRY

The comparison of the two observation techniques was also based on a study of the literature. The authors of this study conducted several relevant studies and studied much of the literature (including electronic database search) that was considered in this study.

2.1. Ergonomic Risk Assessment

Ergonomics is a science that studies the interactions of people with the work environment, taking into account the functional characteristics, abilities and limitations of people in the design of work systems, so that people can work with safety, comfort and efficiency parameters, [8]. The assessment of ergonomic risks is particularly important at the workplace because by identifying the risks that can affect workers, preventive and control measures for these risks can be taken in advance [9].

2.2. Work Posture

The posture of the body during the activity is especially important. The further away from the neutral position the position, the higher the risk of illness. To this are added the multiplication factors such as: the force exerted, the repeated movements, the duration of the effort, etc. A good working posture is determined by the movement and positioning of the body parts during work, corroborated with the duration in which the worker stays in this posture.

2.3. Workstation Design

The design and arrangement of the workstation must take into account the avoidance of awkward positions for workers. The design of the workstation must be able to adjust to the workers to provide comfort, safety and the best work performance. The dimensions of the workstation must be able to be adjusted and adapted to the anatomy and movement needs of the worker's body.

2.4. QEC

Quick Exposure Check (QEC) is a method of occupational risk assessment associated with muscular disorders that analyzes and evaluates how the trunk, shoulders, arms, wrists and neck are affected during activities. [2-5]. According to the QEC methodology, these main parts of the body that are evaluated in terms of ergonomic risks are presented in Table 1.

QEC contributes to the identification of problems related to ergonomics and, through this, the necessary measures can be taken to prevent the occurrence of WMSDs (Work-related Musculoskeletal Disorders), acting on causes such as: repetitive movements, compressive forces, incorrect posture and duration of effort [8].

Table 1. Body parts that may be affected by ergonomic risk factors

Notation in the QEC questionnaire	Body parts	In relation with
A, B	Back	Back posture, weight, duration, frequency
C, D	Shoulder/Arm	Height, weight, duration, frequency
E, F	Wrist/hand	Repeated motion, force, duration, wrist posture
G	Neck	Neck posture, duration, visual demand

The QEC method combines the assessment of the posture observed by the researcher and the factors related to the exerted force, visual precision, stress, from the perspective of the operator or the respondent.

The total load rating can be calculated by combining the estimate made by the assessor (A-G) and the workers (H-P).

The exposure level (E) is calculated based on the percentage resulting from the total exposure of the score thus calculated (X) with a total maximum score (X max) [10], as presented in equation (1).

$$E(\%) = \frac{X}{X_{\max}} x100\% \tag{1}$$

Explanation of terms:

X = Total score, obtained from sum of scores (back + shoulder/arm + wrist/hand + neck);

Xmax = Maximum total score for working posture (back + shoulder/arm + wrist/hand + neck);

Xmax is a constant for certain type of tasks. If the body is in a static position (sit or stand without repetition and relatively lower load) then the maximum score is: Xmax = 162.

The maximum score: Xmax = 176, gave when the worker did manual handling such us lifting, pushing, pulling and carrying loads.

2.5. RULA

RULA was developed by Dr. Lynn Mc Atamney and Dr Nigel Corlett [6]. RULA is an ergonomic risk assessment method that investigates and assesses the working position of the upper body.

This method is used to assess work posture by analyzing a posture sequence from a work cycle, the posture sequence that is considered to have the greatest risk to workers, and then the score is calculated.

QEC and RULA are composed of manual procedures to obtain results and scores based on observations and specific tabular parameters.

Applying these procedures takes about 5 minutes for the observer to calculate scores for a single task. When the tasks to be evaluated are not many, this time is acceptable. But, in general, in real production environments, the number of tasks to be analyzed is large, and then the application of QEC and RULA methods can be time-consuming. [11, 12].

Table 1 shows the main characteristics of the two methods QEC and RULA. With X it was noted that the respective method takes into account the respective characteristic, even to a greater or lesser extent, and with the sign – it was noted that the respective characteristic is not represented in the method.

Table 2. General characteristics of QEC and RULA

Assessment factors	QEC	RULA
Posture		
Back	X	X
Shoulder/Arm	X	X
Wrist/Hand	X	X
Neck	X	X
Legs	-	X
Static posture	X	X
Maximum weight handled	X	X
Time	X	X
Repeated movements / frequency	X	X
Maximum force level exerted by one hand	X	-
Visual demand	X	-
Drive a vehicle at work	X	-
Vibrations	X	-
Work pace	X	-
Stress	X	-

3. DATA COLLECTION FOR QEC & RULA

To collect data in this study, where used several techniques, such as: observing the posture of the workers when they perform the activities, interviewing the workers regarding the ease or difficulty with which they perform these activities and evaluating the posture of the workers during the performance of the tasks, taking into account the posture that can affect the worker the most. Before that, there were discussions with the supervisor and the employees to understand the production process, the work processes and the activities carried out by the workers, especially the activities that affect them the most.

Fig. 1 shows the conveyor belt, the trolley, the dimensions of the work space and the posture of the worker can be observed during the transfer of the parts from the conveyor belt to the trolley.

FIG. 1. Conveyor belt, trolley, workspace dimensions

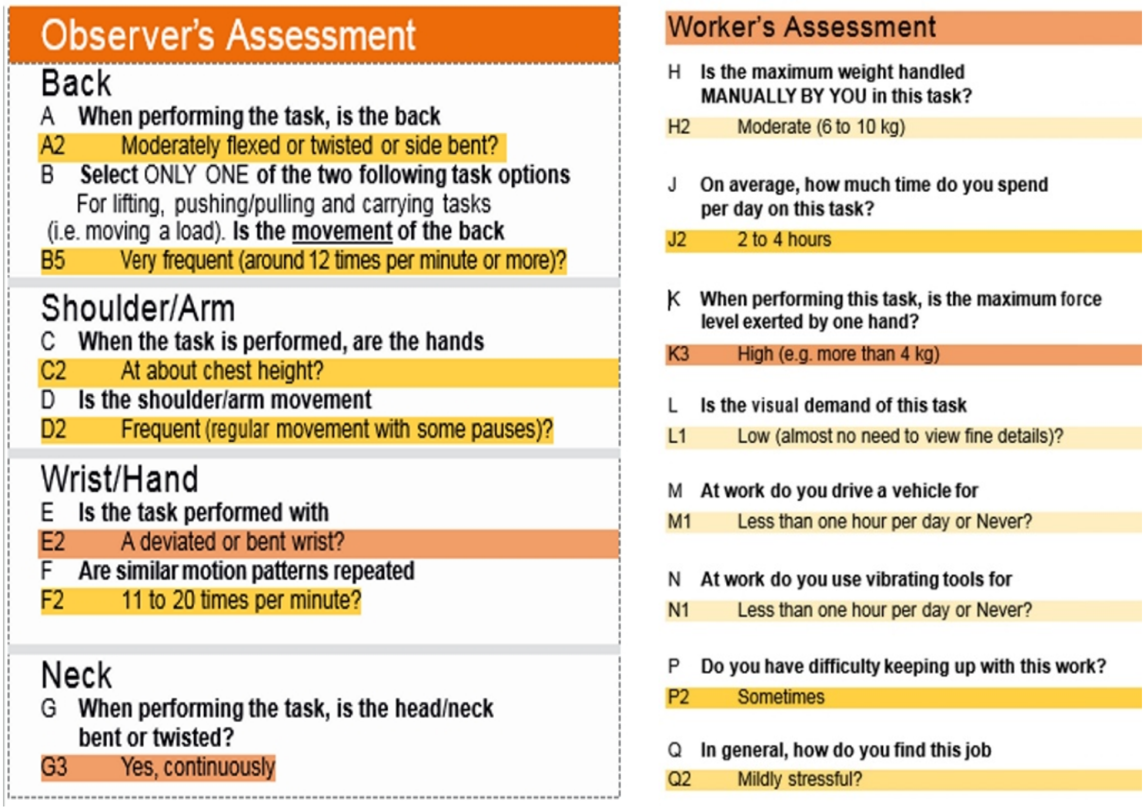
Figure 2 shows the position of the worker when he takes over the parts from the conveyor belt and Fig. 3 shows the worker's position when placing the parts on the trolley.

FIG. 2. The position of the worker when he takes over the parts from the conveyor belt

FIG. 3. The worker's position when placing the parts on the trolley

By observing the work stations, as can be seen in Fig. 2 and 3, it becomes obvious that in order to move the parts from the conveyor belt to the trolley, the workers practically rotate their torso by about 180 gr, tilt their torso, stretch after the pieces, and if they have to place the parts at the bottom of the conveyor, then they tend to tilt their neck too much.

In Fig. 4 (a) and (b) values for the Observer's assessment and Worker's assessment are presented.



Observer's Assessment

Back

A When performing the task, is the back

A2 Moderately flexed or twisted or side bent?

B Select ONLY ONE of the two following task options

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands

C2 At about chest height?

D Is the shoulder/arm movement

D2 Frequent (regular movement with some pauses)?

Wrist/Hand

E Is the task performed with

E2 A deviated or bent wrist?

F Are similar motion patterns repeated

F2 11 to 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

G3 Yes, continuously

Worker's Assessment

H Is the maximum weight handled MANUALLY BY YOU in this task?

H2 Moderate (6 to 10 kg)

J On average, how much time do you spend per day on this task?

J2 2 to 4 hours

K When performing this task, is the maximum force level exerted by one hand?

K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

L1 Low (almost no need to view fine details)?

M At work do you drive a vehicle for

M1 Less than one hour per day or Never?

N At work do you use vibrating tools for

N1 Less than one hour per day or Never?

P Do you have difficulty keeping up with this work?

P2 Sometimes

Q In general, how do you find this job

Q2 Mildly stressful?

(a) (b)

FIG. 4. (a) Observer's assessment, (b) Worker's assessment

The evaluation form shown in Figure 4 shows values for different parts of the body, which, if correlated, can provide a clearer picture of the effort that the worker's body puts into carrying out this activity.

For example, for the back, although we are in situation A2, in conjunction with B5, which means that the movement of the back in these positions is very frequent, it is understood that the worker's back is overloaded when performing this activity.

A similar situation characterizes the wrist/hand, because in most cases where parts are handled, the wrists are flexed close to the natural limit, thus causing great tension in the muscles, tendons, ligaments. At the same time, the neck is almost permanently turned and tilted, especially when placing the pieces in the trolley, and at the base of the trolley, because it has to bend even further, while looking for the right place to place the piece. These related aspects justify the workers' response that sometimes they can't keep up with the pace at work and that the respective activity creates quite a lot of physical and mental stress for them.

Fig. 5 shows the evaluation by means of the RULA method of the same working position.

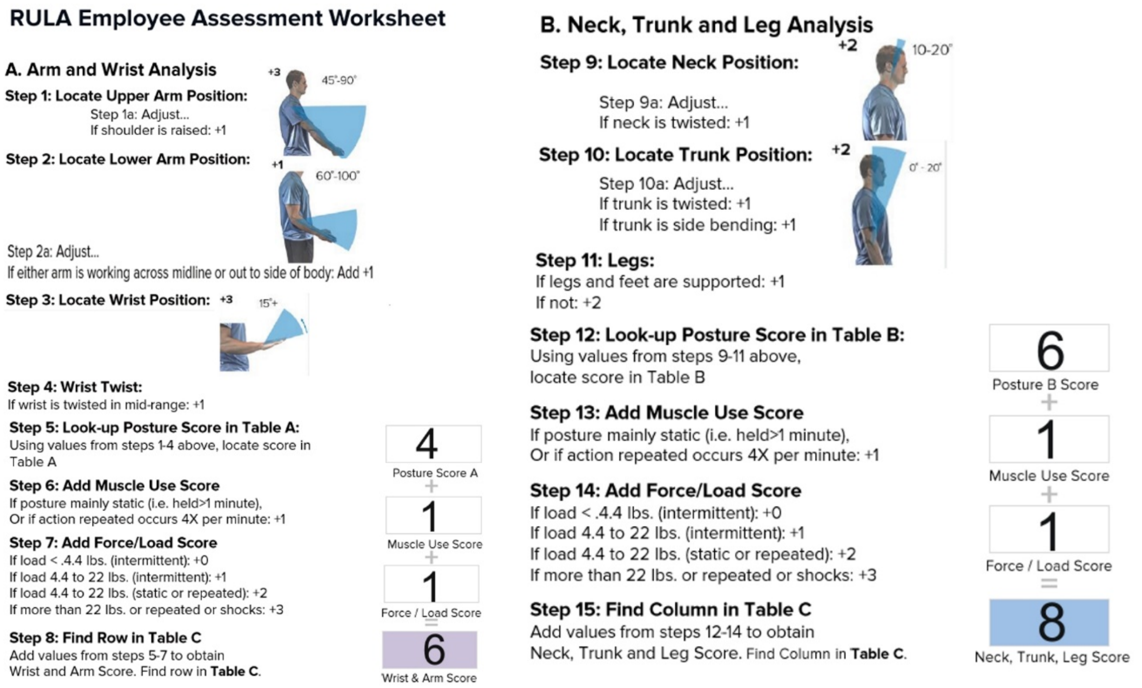


FIG. 5. RULA assessment worksheet

Figure 5 shows the results obtained by applying the RULA method for the same activity. Of course, the scores and the approach are specific to the RULA method and differ slightly from the QEC method scores, but, in principle, the results should lead to similar conclusions. From the calculation of scores while applying the RULA method, quite a few similarities can be observed in relation to the results obtained by the QEC method, as shown below.

4. RESULTS

As part of the risk assessment, a number of 14 workers were analyzed for this activity. Table 2 shows the important characteristics of these workers, compared to the requests they are exposed to, when they perform this activity.

Table 3. The characteristics of the evaluated workers

No	Man/ Woman (M / W)	Height (cm)	Age (years)	Experience in this activity (months)	The physical condition of the worker (Athletic, Good, Weak)
1	M	172	28	22	A
2	M	170	31	14	G
3	M	168	28	28	G
4	M	181	42	32	G
5	W	157	38	14	G
6	W	163	27	14	G
7	M	172	25	22	A
8	W	166	27	22	W
9	M	181	30	26	A
10	M	175	44	28	W
11	W	162	30	20	G
12	M	168	49	32	G
13	M	178	32	18	W
14	M	174	29	26	G

The physical condition of the worker during an activity, especially if the respective activity involves physical effort (e.g. manipulation of masses), or postural effort (e.g. standing, bent trunk), or combined efforts, is an important factor in ergonomics, because the same effort under the same conditions is perceived and felt very differently by the worker if they have a good physical condition or not (if the worker is tall or short, if they have more or less physical strength, etc.), or if they possess more or less developed skills to face this effort. For these reasons, the physical condition of the workers was recorded.

Using the calculation tables specific to the RULA method, the resulting final score is 7, which according to Table 4, represents the maximum score.

Table 4. Scoring: final score from Table C

Scoring	Actions
1 - 2	acceptable posture
3 - 4	further investigation, change may be needed
5 - 6	further investigation, change soon
7	investigate and implement change

In order to be able to compare the results of the two methods QEC and RULA, a correspondence table (Table 5) of the results of the two methods is needed.

Table 5. Correspondence matrix

Risk level	QEC-Exposure Score (E)	RULA
1	$\leq 40\%$	1 - 2
2	41 – 50%	3 - 4
3	51 – 70%	5 - 6
4	> 70%	7

By replacing in equation (1) the data obtained by means of the QEC questionnaire and from the tables containing the exposure scores, presented in equation (2), a final score of 122 results, which means an exposure of 69.32%, which is very close to the level of maximum risk.

$$\mathrm{E}(\%) = \frac{X}{X_{\max}} x100\% = \frac{122}{176} x100\% = 69{,}32\% \qquad (2)$$

Analyzing the results obtained by the two methods QEC and RULA and taking into account the table of correspondence (Table 5), it is found that the results obtained by using the two methods are broadly similar, but still differ to a certain extent.

5. DISCUSSION

As shown, although they are easy to use and lead to quite accurate results, the QEC and RULA methodologies can sometimes lead to different results or conclusions, because they do not take into account a number of factors or ergonomic working conditions that can affect, in many situations, the state of health of the workers.

Although the methods used in the evaluation of ergonomic risks for conveyor belt activity, QEC and RULA, lead to close diagnoses, and in the particular case analyzed, to a high level of risk, and it is considered that these methods are fast and offer a degree of precision of acceptable diagnosis, however, due to the fact that these methods (as well as others) for evaluating ergonomic risks do not take into account the physical condition of the worker (except to a small extent and indirectly), they can even give an erroneous diagnosis of the situation evaluated from ergonomic point of view. In the cases evaluated in this study, these aspects were taken into account, so that, based on the resulting diagnosis, appropriate remedial measures can be proposed, to avoid affecting the health and safety of the workers.

In order to compensate to some extent for the said limitations of the assessment methods, the experience of risk assessors in the ergonomic analysis of the entire work situation is particularly necessary.

CONCLUSIONS

The position of the worker's body influences their efficiency in the conveyor belt activity, and this also emerges from the evaluation results, which show that the operator's risk level score at the workplace is 3 (QEC) and 4 (RULA), but these values are very close. Based on the results obtained from the QEC&RULA analysis, it can be observed that the Exposure Level perceived by the worker is quite high, so that the worker's posture requires immediate improvement. A good posture of the worker definitely leads to an increased work productivity. Comparisons between methods showed a positive association between QEC and RULA, so we recommend using these two methods simultaneously to assess the posture of workers in similar tasks.

In conclusion, this study showed that workers who move parts from the conveyor belt to the trolley and vice versa are at risk of WMSD and improving risk control may involve the implementation of appropriate ergonomic training and education programs for workers. Also, the results of the present study indicate the need to implement preventive programs in the industrial environment to control those risks that lead to more severe musculoskeletal disorders in workers.

In order to investigate in more detail some causes of musculoskeletal disorders in workers, additional investigations are needed, depending on the type of conveyor belt, its height and the height of trolleys, as well as the position of the worker in relation to the conveyor belt and the trolley.

In this sense, our current and future research aims to improve these methods by adding certain elements that in practice have a substantial impact on ergonomics and on the health of the workers. For example, in addition to the height of the work plane compared to the height of the worker, most of the time, in reality, the physical condition of the worker when performing the respective activity or the conditions of the work environment, such as the ambient temperature in which the activity is carried out, also matter, because a low temperature can obviously have a greater impact on the worker's health, especially if the body is not previously prepared to exert effort in these conditions.

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