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Research Article

Analysis of Working Postures in Rubber Manufacturing Industry by using OWAS and RULA Methods

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ABSTRACT

The basic conditions of working in a healthy and safe workplace are to design the job in accordance with the anthropometric measurements, body strength and personal characteristics of the person, to ensure that the materials, machinery and equipment used in the working process are suitable for the employee's capacity, and to provide an environment that will produce positive psycho-social results. Correct analysis methods should be used and evaluated in order to meet this basic requirement. Identifying the negative effects of working postures, taking corrective measures and improving them is a critical step of an efficient working environment. Working postures that are not properly analyzed cause strain on workers and even discomfort. It provides important contributions in the field of analyzing and improving working postures with scientific methods, controlling work performance and reducing musculoskeletal disorders (MSDs). OWAS (Ovako Working Posture Analyzing System) and RULA (Rapid Upper Limb Assessment) are successfully applied in various fields in the analysis of working postures. In this study, it was aimed to determine the MSDs risk levels of the workers working in the rubber industry by OWAS and RULA methods and measures were proposed for these risks. While OWAS analysis was obtained by using expert opinions in the study, CATIAV5R20 program was used for RULA analysis. The study includes the examination of 5 different postures in total. In the OWAS and RULA results of the study, it was seen that the most risky postures are attach the rubber hose to the cores and to place the rubber hoses attached to the cores in the autoclave. The results of the analysis showed that the RULA method is more suitable and reliable than the OWAS method for the analysis of the tasks in the vulcanization process workstations.

1. Introduction

At the beginning of the 19th century, ergonomic concepts were developing to increase worker productivity, as industrial production was still heavily dependent on manpower. Frank and Lillian Gilbreth have made work more efficient and less tiring by standardizing materials and work process with time motion analysis and tools. The Second World War sparked more interest and research into human-machine interaction, especially in complex military equipment. Design concepts were developed to fit the machine to the soldier's size. II. During World War II, the focus was on worker safety, as well as initiating many new research and practices, thereby concentrating on studies in this area [1].

Ergonomics was first defined and proposed by the Polish scientist B. W. Jastrzebowski as a scientific work study discipline with a wide range of interests and applications covering all aspects of human activity [2]. Ergonomics is an engineering discipline that examines the interaction between humans and machines and the factors affecting this interaction in detail. It aims to minimize the negative effects of interacting factors on people and enables individuals to maximize their contribution to the work [3]. According to the International Ergonomics Association, ergonomics is defined as the scientific discipline concerned with understanding the interactions between people and other elements of a system, to design theory, principles, data, and methods to optimize human well-being and overall system performance [4].

Improving musculoskeletal health in the workplace is one of the most important goals of ergonomics. Westgaard and Winkel [5] defined physical effort as “mechanical forces created to meet job demands, taking into account level, repeatability and duration”. According to the International Ergonomics Association (IEA), physical ergonomics issues include “working postures, material handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health” [4]. Musculoskeletal health can be protected by controlling risk factors. Biomechanical hazards, genetic predisposition, morphological disadvantages, and psychosocial disposition are instrumental in the occurrence of work-related musculoskeletal injuries, but it is also possible to control these injuries. Physical exertion in the workplace can lead to an increase in work-related musculoskeletal injuries. As working postures and movements are two of the important mechanical variables and load determinants, they are important variables to be considered in terms of occupational safety.

A clear definition of posture cannot be found in the ergonomics literature. Depending on whether the context in which it is used is anatomical or biomechanical, it can be regarded as the configuration of the body in space of the head, trunk, and limbs, or "quasi-static biomechanical alignment." The functional aspects of stance are emphasized by the definition of 'the position adopted because it suits the task being performed' [6]. Posture is defined in various ways, taking into account the biomechanical arrangement, the spatial arrangement of body parts, the relative position between parts, and the body attitude that is supposed to perform tasks. Posture is affected by the task,

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the workstation, the design of work tools, and the anthropometric characteristics of workers [7]. Posture is the current body position at the time of doing the work. The neutral position is defined as the position where the joints and the body are the least stressed and the least energy is spent during the workout. Ensuring and maintaining the neutral position determined for the spine and each joint is the basis of the health of the waist, back, neck and all joints. For this purpose, ergonomic arrangement of the workplace is an important issue [8].

Therefore, in this study, it was aimed to determine the risk levels of MSDs of workers working in the rubber industry by OWAS and RULA methods, and measures were suggested for these risks. The remainder of the study is organized as follows; In the second section, OWAS and RULA methods, which are the analysis methods of working postures, are presented, and in the third section a literature study including the two methods is included. The fourth section of the study includes the analysis results in the production unit. In the last section of the application, evaluations about the study are included.

2. Analysis of Working Postures

MSDs are among the most common health problems in terms of both their incidence and the time and money spent on these disorders. This situation, which is mainly caused by poor working posture, also negatively affects employees in terms of work efficiency, quality of life and both physical and social activities. It makes significant contributions to the analysis and improvement of working postures with scientific methods, controlling work performance and reducing MSDs. The main purpose of this type of research is to find anthropometric mismatches between worker and workstation design to reduce MSDs risks and increase productivity [3]. OWAS and RULA are two methods of analyzing work postures to assess individual worker exposure to ergonomic risk factors associated with musculoskeletal disorders and can be successfully applied to a variety of fields [9, 10]. There are examples of OWAS and RULA analyzes applied separately or together in many sectors in the literature. In this study, these two methods, which can be applied to every sector, were preferred. OWAS and RULA methods require robust analysis of working postures to accurately identify ergonomic risks. OWAS, which is an easy method that can be calculated manually and practically in the evaluation and analysis of working postures, was considered sufficient for the initial analysis since it can be applied by people who have not received ergonomics training [11]. It was also preferred in this study because it provides an overview of ergonomic analysis by including basic posture and load levels such as back, leg, arm, load/force. However, in this study, which was carried out in a labor-intensive production workshop, it was deemed appropriate to use the RULA method, which was designed to support the rapid analysis of pressures on a worker's upper limbs in addition to the OWAS method. This provides a more practical conclusion about which body region is at more risk from the methods discussed. These methods are briefly described below.

2.1. OWAS Method

OWAS is an observational study posture analysis method that helps determine the load on the musculoskeletal system of workers, inappropriate postures and repetitions caused by the system, and optimal working methods. It also enables the workplace to be evaluated in terms of productivity, comfort and occupational health and to systematically investigate the human-machine junction. According to this method, the postures are classified and the postures and elements that need to be systematically improved and developed towards a design are determined in order to eliminate the factors that disturb the worker [11]. The OWAS method was developed by Ovako Oy's Fininish steel company. The basis of the method is based on the degrees of working postures taken in various parts of a steel mill, performed by 32 experienced steelworkers and international ergonomists. The OWAS describes four working positions for the back, three for the arms, seven for the lower limbs, as given in Table 1, along with the weight of the load arms or the amount of force used 252 (4×3×7×3) with its combination, it creates general scores containing 4-digit codes as in Table 2. Then, with the help of Table 3, the relevant action code is found [12, 13]. The technique then classifies the combinations of these four categories for all posture combinations according to the degree of their effects on the musculoskeletal system, as in Table 4, allowing the stance-load combinations to be divided into four action categories that indicate the urgency of necessary workplace interventions [12].

Table 1. Definition of Postural Codes in OWAS

Body	OWAS Degree	Definition of Posture
Back	1	Straight/upright
	2	Bent forward
	3	Straight and twisted
	4	Bent and twisted
Arm	1	Both arms below shoulder height
	2	One arm above shoulder height
	3	Both arms above shoulder height
Leg	1	Sitting
	2	Standing on both legs straigh
	3	Standing on one straight le
	4	Standing on both legs bent
	5	Standing on one bent leg
	6	Kneeling on one or both legs
	7	Walking
Force (Kg)	1	Less than 10kg
	2	More than 10kg less than 20kg
	3	More than 20kg

Table 2. The four-digit matrix in OWAS

BACK	ARM	LEG	FORCE

Table 3. Common impact action code in OWAS

OWAS Method Common Impact Action Code																							
			Leg																			
			1			2			3			4			5			6			7		
			Force			Force			Force			Force			Force			Force			Force		
		Arm	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Back	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
	2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
		2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
		3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
	3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
		2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
		3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
	4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
		2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
		3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

Table 4. The four action categories in OWAS

Category	Action category/level	Explanation
1	Normal posture	Normal positions that do not require any special caution
2	Not too much forced	During the next regular check of working methods, stops must be considered
3	Too load and force	Positions must be taken into consideration soon
4	Loading and forcing too much	Positions need to be evaluated immediately

2.2. RULA Method

McAtamney and Corlett [14] developed the RULA tool for rapid risk assessment of upper limbs, neck and trunk posture, i.e. upper extremity disorders, taking into account muscle function and load value. The RULA assessment generates a list of action categories with a code that indicates the level of intervention required to reduce the risk of employee annoyance. RULA examines the severity of risk factors and combines all risk factors to give an overall score ranging from 1 to 7. Table 5 includes the evaluation of total scores according to risk levels.

Table 5. Action categories in RULA

RULA score	Risk level	Action to be taken
1-2	Negligibl e	Acceptable posture if it is not repeated for longer period
3-4	Low	Further investigation and change may be needed in future
5-6	Medium	Investigation required and change needed soon
7	High	Investigate posture and change needed immediate

In this study, RULA analysis was performed on a fully replicated manikin using CATIA to assess the postural discomfort level of workers. In CATIA, RULA final scores are displayed with a color code. The color changes from green for the "negligible risk" level to red for the "high risk" level based on the final scores achieved. The green color is an indication of an acceptable stance if not repeated for a long time, which is to achieve a final score of 1 and 2 points. Yellow color with final scores of 3 and 4 is an indication that more research is needed and that posture changes may occur in the future. A final score of 5 and 6 i.e. orange color explains that more research is needed and the stance needs to be changed in the near future. A final score of 7 in red highlights the need for evaluation and immediate change of stance. The summary of color codes is shown in Table 6 [3].

Table 6. Color code in CATIA-V5 and RULA Score

Segment	Score range	Color associated to the score					
		1	2	3	4	5	6
Upper arm	1 to 6	green	green	yellow	yellow	red	red
Forearm	1 to 3	green	yellow	red	grey	grey	grey
Wrist	1 to 4	green	yellow	orange	red	grey	grey
Wrist twist	1 to 2	green	red	grey	grey	grey	grey
Neck	1 to 6	green	green	yellow	yellow	red	red
Trunk	1 to 6	green	green	yellow	yellow	red	red

3. Literature

Terra et al. [10] in their study at the radiology service outpatient reception station, RULA and the Rapid Office Stress Assessment (ROSA), a new method of measuring exposure to risk factors in an office work environment, aimed to confirm the likelihood of musculoskeletal diseases affecting workers due to postures adopted in the work environment. It has been proved that both methods are compatible with each other by revealing that they reach the same level. Zhang and Lin [13] modeled the behaviors of the employees while performing their duties and the ergonomic measures that can be taken for these behaviors, taking into account different physical capacities such as different worker ages. Iqbal et al. [15] aimed to analyze the working postures of Tofu factory operators using the Cornell Musculoskeletal Disease Questionnaire (CMDQ) and RULA method for operators working in a tofu factory in Banda Aceh, Indonesia. Recommendations for improvement in body posture and reducing the risk of injury to the operator have been to determine the working tools and rest hours and working time according to the standards. Gawliński and Łyp-Wrońska [16] investigated the effects of using two methods from the field of ergonomics (OWAS and Lehmanns' table-chronometric method) in modern logistics engineering in a company producing agricultural machinery. The analysis results show that it can be beneficial in ergonomically improving the logistics of the production process. Cimino et al. [17] developed a simulation-based risk assessment framework combined with ergonomic methods (OWAS, 3D SSPP/SSP, MFA, LBA, CBL, GARG, STRAIN INDEXES, NIOSH 81/91) and Analytical Hierarchy Process (AHP). In an Italian container terminal discussed in the application, first, processes and tasks were analyzed to develop a simulation model that could reproduce the development of the real system over time, and in the next step, ergonomic problems related to tying/untie operations were determined by applying ergonomic methods with the simulation model. Finally, AHP was used to analytically rank critical ergonomic operations and prioritize interventions. Pandit et al. [18] studied different physiological and musculoskeletal disorders caused by poor ergonomic postures in elderly female farmers using RULA and REBA (Rapid Entire Body Assessment) methods. The results showed that most of the postures were risky and increased pain and discomfort in the neck, upper and lower extremities, carrying the load repeatedly was seen to be the main problem of ergonomic discomfort in elderly female farmers. Brazil et al. [19] conducted a study that analyzed the repetitive and tiring tasks of a cleaning staff in a hotel with RULA. Bawiskar et al. [20] aimed to determine the occupational stress of the postural burden of sculpting on craftsmen by analyzing 120 craftsmen with RULA and REBA methods. It has been determined that artisans in the advanced age group experience pain in upper extremity body parts such as palms, neck, and shoulders due to repetitive sculpting work. However, it has been observed that the younger age group has more discomfort in the back. Varghese et al. [21] used the OWAS method in their study to examine workers who, while performing an operation to remove latex of certain wood species called rubber tapping, had to assume awkward postures, including stretching arms of the neck, trunk, and wrists, side bending, twisting, flexing, and/or extension. Nedohe and Makinde [22] investigated the ergonomic conditions of welding workplaces to detect the defects that may be related to the working posture during welding operations. Malhotra and Chauhan [23] aimed to investigate the postures and related musculoskeletal problems experienced by 200 female residential cleaners with an average age of 38.4 working in the city of Mumbai. A standardized Scandinavian questionnaire was chosen to assess MSDs issues and OWAS for posture analysis. Results: 85.5% of scavengers reported low back pain, 83% shoulder and 52% calf pain. Kamble et al. [24] investigated the working postures of artisans using RULA and Occupational repetitive actions method (OCRA) through an observational study and a self-reported questionnaire study with a sample of 70 printing presses. The findings show that the artisans working in the printing house are at high risk for MSDs, therefore, urgent intervention is required to eliminate the ergonomic risks among the tradesmen. Kee et al. [25] compared three representative observation methods, OWAS, RULA, and REBA, to measure maximum holding times (MHTs) for symmetrical and asymmetrical body postures. Based on the findings of this study, it was concluded from the three observational methods that RULA may be better for assessing postural loads under experimental conditions. Hussain et al. [3] analyzed the working postures of physical workers in small-scale industries with the RULA method in the CATIA V5R20 program. It has been observed that the workers work in strange postures such as heavy lifting, bending, turning and turning the body by hand in stone cutting and polishing works. Most of the postures showed a high-risk score of 7. Improved posture after recommending ergonomic interventions was assessed using RULA and scaled with 3 points indicating low risk. The manual lifting task was also evaluated using the NIOSH lifting equation. Ergonomic interventions have reduced the lift index value to the safe limit. The results show that the risks of uncomfortable working postures can be minimized with the effective use of ergonomic interventions. Brandl et al. [26] evaluated based on 20,601 observations of 63 semi-trailer assembly workers. Ergonomic analysis of working postures in semi-trailer assembly using OWAS revealed that existing postural loads can have a detrimental effect on the musculoskeletal system and therefore corrective measures should be taken as soon as possible. Lee and Han [27] used OWAS to analyze the working postures of three construction workers with an average of 40 years of work experience while constructing the foundations of a log cabin. This study suggested that workers should be reminded that they should be aware of their posture and step orientation so that the trunk is not twisted, they take adequate rest time during work, and reduce the time spent in each bad posture. Nwe et al. [28] using OWAS, the physical workload during pruning and fruit thinning in vineyards located on a hillside and plain was evaluated and pruning was a heavier workload than fruit thinning regardless of farm topography, and slope work was found to be heavier for both operations. conclusion has been reached. Ketan et al. [29] analyzed working postures for manual handling of laminations at a stacking workstation for a water pump assembly line in Baghdad with a computer program called WinOWAS. It was found that more than 26% of observed operating postures were classified as AC2 (somewhat harmful), AC3 (significantly harmful). The AC2 postures are listed from the WinOWAS output and the most problematic working postures found for work were found to be bending the back and squatting/kneeling on both legs. The most stressful tasks observed were grasping, transporting, and positioning laminates from workers. It is concluded that the OWAS method is suitable and reliable for the analysis of tasks on assembly workstations. Li and Lee [30] analyzed 2,880 working postures for form, scaffolding, iron, and cement works at two construction sites in northern Taiwan. CCOWAS, a computer program, was designed for the study. It was found that more than 30% of the observed operating downtimes were classified as AC2 (somewhat harmful), AC3 (significantly harmful) or AC4 (extremely harmful). Qutubuddin et al. [31] evaluated the operator's position in the cold forging machine with RULA using CATIA software and obtained 7 points, which means high risk. After implementing ergonomics intervention and workstation redesign in CATIA, the improved posture resulted in a final RULA score of 4, indicating moderate risk. According to Nugraha et al. [32] aims to determine and compare the before and after RULA Score for improving workplace design in SMEs producing concrete bricks. Analysis methods, CATIA and RULA are used on the motion element that is fragmented by Theblig methods. The result of the research showed that workplace improvement successfully reduced ergonomic risk levels by 43%. Ibrahim et al. [33] analyzed the anthropometric data of the Multi-Purpose Vehicle (MPV) driver using the RULA technique. According to the results obtained, it was seen that the sitting posture did not fully fit the MPV driver's seat, as the overall RULA assessment showed it in Elayaraja et al. [34] made an ergonomic posture assessment of the drilling machine employees using digital human modeling (DHM).The result from the RULA assessment revealed that the employee was experiencing muscle fatigue, and 7 points indicated a high level of risk at the current workstation. The workstation has been redesigned according to anthropometric measurements. RULA scores decrease from 7 to 4 in the redesigned posture. Rabbika et al. [35]carried out an ergonomic risk analysis with RULA for before and after a motor-controlled valve system to irrigate a factory established on agricultural land. The results of the study showed a 75% reduction in ergonomics risk.

4. Case study

The application includes the analysis of the vulcanization process in the production department where musculoskeletal disorders are most common in a company that manufactures and sells braided/unbraided rubber hose, rubber bellows and plastic parts for the automotive and other industry sectors. The autoclave used in the vulcanization process where the application is made is given in Figure 1, and the process of rubber production is given in Figure 2.

Fig. 1. Autoclave used in the vulcanization process

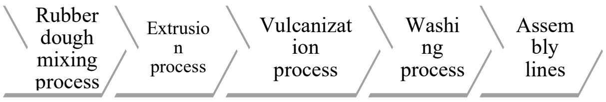


Figure 2. Workflow of Production

In practice

Posture 1 Removing the cores from the warehouse shelves

Posture 2 Moving to the production area where the process will take place.

Posture 3 Attaching the rubber hose to the cores

Posture 4 Autoclave insertion of rubber hoses attached to cores

Posture 5 washing process of vulcanized rubber hose

were taken into consideration within the scope of analysis. In line with the information received from the experts in the relevant production workshop, the postures examined were discussed in the study because it is the process in which the disorders in the musculoskeletal system are seen most intensely. Posture images obtained with the CATIAV5R20 program, respectively, of the relevant steps are shown in Figure 3. Digital Human Modeling (DHM), the process of CAD representation of the human body form, is an emerging tool used to simulate workplaces to provide solutions to ergonomics-related problems. The digital people/mannequins included in the software can be easily manipulated and evaluated for work-related discomfort, injuries and workplace design. Manual workers in small-scale industries often experience work-related discomfort and pain while performing the job. These exposures can affect worker productivity and industry productivity by leading to the development of work-related musculoskeletal disorders (WRMSDs) and low back pain (LBP).

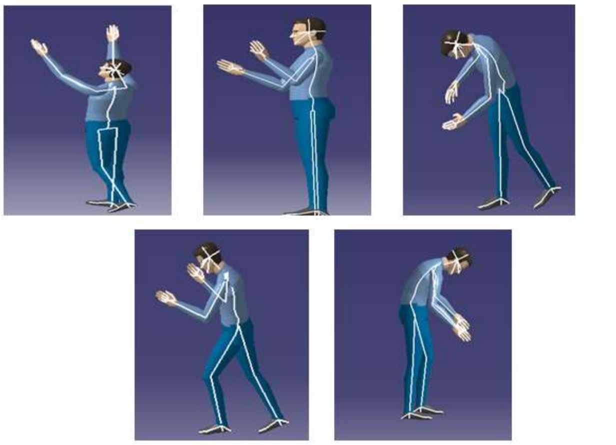


Fig. 3. From right to left, Posture 1, Posture 2, Posture 3, Posture 4, Posture 5

The application is in the nature of a case study and includes the evaluation of two analysis methods separately. The body posture of the worker was examined and the OWAS analysis, which is one of the moving working methods, was carried out on the real working postures taken from the production. The grading of body postures in Table 1 was evaluated by expert opinions, and as a result, the four-digit code in Table 2 was obtained. The four-digit code corresponding to each value is marked in the joint effect action table in Table 3. The action category level was obtained from the intersection of the relevant row and column. The result obtained was evaluated according to the risk levels in Table 4. The evaluation was repeated for each posture and the results obtained are included in the 5th section.

Photographs of working postures taken from production were converted using CATIA software to perform RULA analysis in practice. After the relevant load assignments were made, RULA analysis was performed on the fully replicated manikin to assess the postural discomfort level of the workers. Analyzes were repeated for each photograph and the results are shown in section 5. The final result obtained was evaluated according to the risk levels in Table 5.

5. Result and Discussion

The working postures were first obtained in real time for each posture and then the real-time postures were converted to a digital human model using CATIA. Real Working Posture and Digital Human Model of Posture 1 are given in Table 7.

Table 7. Real Work Posture and Digital Human Model of Posture 1

No	Real work posture	Digital human model (DHM)
Posture 1		

The OWAS results seen in Table 8 for posture 1 were included in the C1 level action category in the joint action action code grading, although the force/load level was 3 and the arm level was 3. This resulted in the posture not requiring any special attention.

Table 8. OWAS analysis result for Posture 1

			Leg																				
			1			2			3			4			5			6			7		
			Force			Force			Force			Force			Force			Force			Force		
		Arm	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Back	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
	2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
		2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
		3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
	3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
		2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
		3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
	4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
		2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
		3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

Looking at the RULA results with CATIA in Figure 4, it is seen that the result is in the high risk category and the stance should be changed immediately. Load assignment is set manually in CATIA.

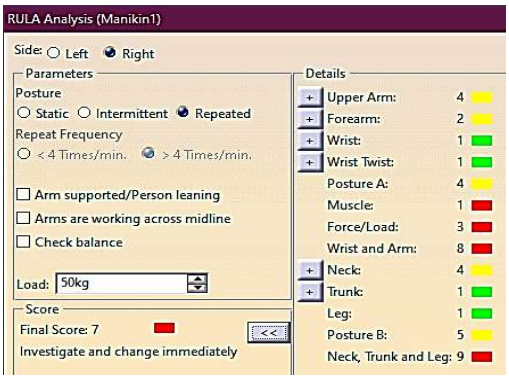
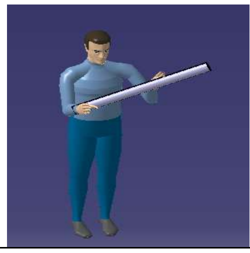


Fig. 4. RULA analysis results for Posture 1

In this sense, it was seen that the load factor included in the OWAS did not have a strong effect as in the RULA analysis. In the results obtained in the stance analysis, it was concluded that the operator had a risky workload, and it was suggested that this result should be taken into account in the improvements to be made here. Storing the cores with the hanger system was the first suggestion that came to mind as it would involve less transport than pulling the crates from the shelves. In cases where this improvement cannot be made due to the cost of the hanger system and the need for more storage space, it is recommended to use ladders to access the crates at high places in order to prevent them from maintaining the same posture by raising their arms. Real Working Posture and Digital Human Model of Posture 2 are given in Table 9.

Table 9. Real Work Posture and Digital Human Model of Posture 2

No	Real work posture	Digital human model (DHM)
Posture 2		

Considering the OWAS results in Table 10 for the 2nd posture, although the force/load level is 3 and the arm level is 2, it is in the C1 Level action category. OWAS results show that this posture does not require any special attention.

Table 10. OWAS analysis result for Posture 2

			Leg																				
			1			2			3			4			5			6			7		
			Force			Force			Force			Force			Force			Force			Force		
		Arm	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Back	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
	2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
		2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
		3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
	3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
		2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
		3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
	4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
		2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
		3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

Considering Figure 5, the final score obtained as a result of the RULA analysis was seen as 6. The results suggest that more research is needed and that posture may need to be changed in the near future. In cases where cores are not carried individually or in cases where they are carried to heavier cores, an increase in the risk situation is an inevitable result. For this reason, it is recommended to add it to the standard work instruction form in order to spread the discipline of using the transport trolley in multi-die transport or uniform die transport in order to prevent the core from being transported for a long time with the arms bent.

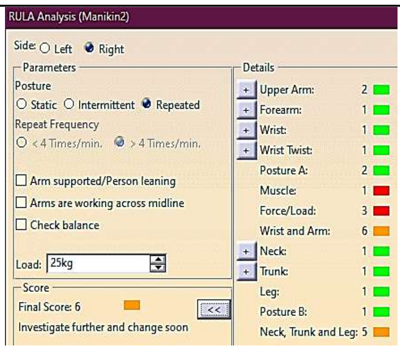


Fig. 5. RULA analysis results for Posture 2

Real Working Posture and Digital Human Model of Posture 3 are given in Table 11.

Table 11. Real Work Posture and Digital Human Model of Posture 3

No	Real work posture	Digital human model (DHM)
Posture 3		

OWAS results of Posture 3, seen in Table 12, are included in the 4th level in the back and load/force analysis and in the C3 Level action category in the joint effect action code grading, and it is seen that the working posture should be evaluated in the near future.

Table 12. OWAS analysis result for Posture 3

			Leg																			
			1			2			3			4			5			6			7		
			Force			Force			Force			Force			Force			Force			Force		
		Arm	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Back	**1**	**1**	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
	2	**1**	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
		2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
		3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
	3	**1**	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
		2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
		3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
	4	**1**	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
		2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
		3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

Looking at Figure 6, the final score of 6 obtained in the RULA analysis shows that posture should be examined in more detail and a more efficient working area should be offered to the employee.

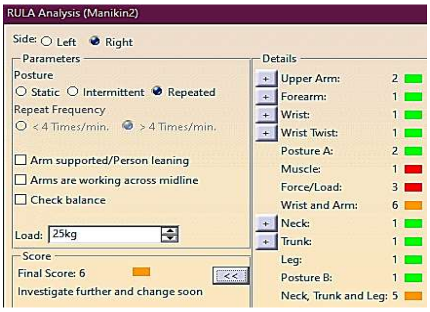


Fig. 6. RULA analysis results for Posture 3

This stance shows that the risk level for both analyzes is above normal. Due to the scarcity of alternatives in labor-intensive jobs, it is only possible to organize the environment according to the worker. From this point of view, it is not possible to attach the rubber hose to the mold with an alternative method. For this reason, the improvement of the operator unit will be the first step to facilitate the work. The vise positioning should be configured specifically for the personnel, and the height of the table and hanger should be revised according to the height of the personnel. It may be advisable to include hand postures in the basic OWAS and RULA or use additional methods to identify ergonomic risk factors for hand-intensive activities. It is also recommended to use a mechanical support system to reduce the workload.Real Working Posture and Digital Human Model of Posture 4 are given in Table 13.

Table 13. Real Work Posture and Digital Human Model of Posture 4

No	Real work posture	Digital human model (DHM)
Posture 4		

When Table 14, which includes the OWAS analysis of Posture 4, is examined, the legs are in the walking position and the load/force degree is at Level 3. This is considered in the C3 Level action category. So it is suggested that the postures be improved in the near future.

Table 14. OWAS analysis result for Posture 4

			Leg																				
			1			2			3			4			5			6			7		
			Force			Force			Force			Force			Force			Force			Force		
		Arm	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Back	**1**	**1**	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
	2	**1**	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
		2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
		3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
	3	**1**	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
		2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
		3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
	4	**1**	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
		2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
		3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

The RULA analysis results in Figure 7 are also somewhat similar but show that the risk level is high and a strong study is essential.

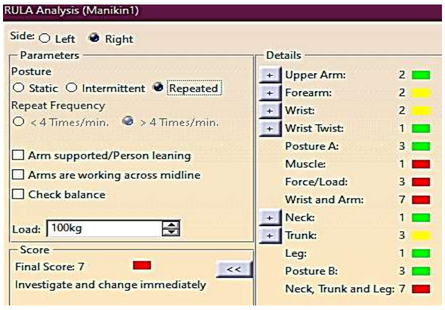


Fig. 7. RULA analysis results for Posture 4

Here, the effect of the environment in which the work is done is more effective than the other stances examined. It has been observed that the ground where the pushing process takes place causes extra effort on the worker. The first critical improvement to be made here should be on the bearing system, an effective rail system to be installed on the bearing system can almost halve the workload. In addition, integrating the automatic rail system in the future will also eliminate the level of risk. Real Working Posture and Digital Human Model of Posture 5 are given in Table 15.

Table 15. Real Work Posture and Digital Human Model of Posture 5

No	Real work posture	Digital human model (DHM)
Posture 5		

Results in Table 16 resulted in OWAS action category C2, although posture 5 continuous oblique back work was demonstrated. It can be said that the strain is not too much.

Table 16. OWAS analysis result for Posture 5

			Leg																				
			1			2			3			4			5			6			7		
			Force			Force			Force			Force			Force			Force			Force		
		Arm	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Back	**1**	**1**	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
		3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
	2	**1**	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
		2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
		3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
	3	**1**	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
		2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
		3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
	4	**1**	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
		2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
		3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

The RULA results in Figure 8 also emphasize that the final score of 5, that is, the stance, should be changed in the near future. However, if it is repeated for a long time, it should not be overlooked that the stance poses a risk in terms of MSD. Machine positioning should be reviewed.

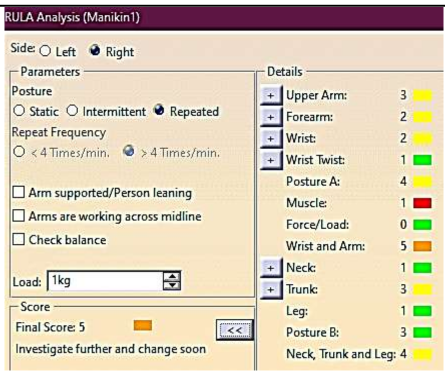


Fig. 8. RULA analysis results for Posture 5

6. Conclusions

Today, various health problems occur due to incorrect postures, missing equipment and non-ergonomic working conditions in the workplace. One of these health problems are MSDs. MSDs are one of the most common negative effects on the working population. MSDs are caused by improper working postures. Even low levels of sustained muscle contraction may represent a risk of causing musculoskeletal injury. Prolonged static postures are not recommended as they will cause discomfort. Therefore, safe levels of skeletal-muscular monotony must be established. An ideal workstation should allow for postural changes to enable working in comfortable and safe environments. The layout of workstations, tasks, and tools used also affects the amount of physical stress workers are exposed to. Acting to check for injuries and damage beforehand can help prevent the onset of dysfunctions. To carry out a successful ergonomic intervention, it is necessary to optimize musculoskeletal functioning and safety while keeping production and costs within manageable limits. At this point, the involvement of top management is important. It is clear that improper working postures produce harmful physical damage that can cause musculoskeletal injury, pain. Excessive effort, fatigue and load explain the cause of musculoskeletal injuries. Studying work postures helps establish ergonomic guidelines for safe work, contributes to better musculoskeletal health in the workplace by reducing biomechanical hazards and improving control of work-related musculoskeletal injuries and disorders. Musculoskeletal disorders are common due to the lack of ergonomic studies in labor-intensive sectors based on manpower.

The study dealt with the ergonomic analysis of postures for the rubber production sector. An assessment of the three major body parts (back, arms, and legs) and upper extremities (wrist, trunk and neck, trunk, and leg) combined with an assessment of force application with the methods used in this study was performed. Looking at the OWAS analysis results of the study, taking the cores from the warehouse shelves and transporting them to the production area where the process will take place resulted in action degree 1, which was the stance with the least risk. The washing process of the rubber hose vulcanized with action grade 2 resulted in relatively low risk downtime. OWAS analysis results were attaching the rubber hose to the core and the insertion of rubber hoses attached to the cores into the autoclave, with action grade 3 of the most risky stance. When the RULA results are examined, it has been seen that the lowest risk level is the washing process of the vulcanized rubber hose with the final score of 5, and the more risky stances with the final score of 6 are transporting the cores to the production area where the process will take place and attaching the rubber hose to the cores. In the RULA analysis, the most risky stances with a final score of 7 are taking the cores from the warehouse shelves and placing the rubber hoses attached to the cores in the autoclave. Considering the results of the two analysis methods, it is seen that the load factor affects the degree of risk more in RULA analysis compared to OWAS. Considering the average scores for both analyzes, it was seen that the most risky working postures were to attach the rubber hose to the cores and the rubber hoses attached to the cores to the autoclave, and it was seen that urgent measures should be taken. The use of mechanical support systems is recommended to ensure that the risk levels in postures are reduced. The OWAS and RULA methods discussed in the study do not consider the total duration of the job, which shows that the analyzes are insufficient for long-term work posture. As a result of the study, it was seen that OWAS was divided into only 3 titles in the load/force category. It may be advisable to include or use additional methods. Another part of the OWAS in this study is that the head postures were not included in the analysis. In addition, temperature, which is one of the important factors forcing the working conditions due to vulcanization, is one of the working difficulties that has not been taken into account in the OWAS and RULA analysis methods. Considering the literature for RULA analysis, it is not clearly stated from which perspective or angle the worker should be observed or whether it can be observed from many points. It cannot be applied to manual lifting jobs that require significant movement within a work area. The method allows to evaluate the right and left sides of the body separately, and since there is no result as a whole body score, it is recommended to examine the different postures in more detail. It should be determined whether it requires ergonomic regulation by using OWAS and RULA methods in other rubber production works that are not applied in this study. Considering the studies in the literature, it has been concluded that OWAS and RULA analyzes can be applied in many sectors and can be used with different methods. However, no study has been found in the literature in which OWAS and RULA methods are used together in the rubber manufacturing sector based on human power. The aim of this study is to fill the gap in the literature and motivate more researchers to apply more to solve various ergonomic problems in rubber manufacturing companies. In order to examine the postures discussed in future studies in more detail, it is recommended to use different working posture analysis methods and to take actions related to improvement and analyze and evaluate the postures.

Declaration of conflicting interests

The authors declare no competing interests.

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