Hittite Journal of Science and Engineering, 2020, 7 (4) 257–264
ISSN NUMBER: 2148–4171
DOI: 10.17350/HJSE19030000194

A Case Study in Ergonomics by Using REBA, RULA and NIOSH Methods: Logistics Warehouse Sector in Turkey

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Article History:
Received: 2019/12/13
Accepted: 2020/09/17
Online: 2020/12/31

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ABSTRACT

Employees in the warehouse processes of the logistics sector are engaged in activities such as pushing, pulling and lifting during a day. Intense work tempo, power requirement, working in unsuitable positions and physical factors of working environment adversely affect employees. The aim of this study is to investigate ergonomic risk assessment of a logistic warehouse in the Kocaeli province, located in the Marmara Region. This study was conducted over a sample area where 57 people work in, 5 work processes in a warehouse with a closed area of 8000 m² and all processes were examined during 4 months. Employees' working postures in daily routine were studied by using REBA, RULA and NIOSH as ergonomic risk assessment methods. Furthermore, ambient noise, personal noise, ambient dust, personal dust, vibration, chemical and thermal comfort values were measured with accredited devices.

Keywords:
Ergonomics; Occupational health and safety; REBA; RULA; NIOSH.

INTRODUCTION

The field of ergonomics science comprises planning to carry out works in accordance with human abilities and capacities while occupational health of employee and minimizing occupational accidents [1]. The aim of ergonomics is to reduce or eliminate situations that may cause musculoskeletal disorders, to prevent incidents and occupational accidents occurring in the workplace [1, 2, 3, 4]. The task of management is to ensure the continuity of a safe work environment and employee safety. These include following the principles of occupational safety in workplace design, equipment selection, providing protective equipment and mechanisms, planning employee training and preparing clear and understandable occupational safety rules [5]. Protecting the health and comfort of the employee is one of the pioneers of work health and safety during the warehousing processes, which is one of the important service areas of the logistics sector. The logistics sector has some processes in working environment of warehousing, such as handling, storage, material handling, packing and stacking. [6].

Intense working tempo and improper working postures may cause musculoskeletal diseases [7]. There exist several ergonomics risk evaluation methods to prevent musculoskeletal diseases [8, 9]. These methods are divided into two as observational and measurement-based techniques [8]. Observational methods such as REBA, RULA, OWAS, BAUA, NIOSH etc. are the the most common mthods used in evaluation [10, 11, 12, 13, 14, 15 16].

Within the scope of this study, logistics sector is undoubtedly one of the most important areas for storage activities [5, 6]. The main aim of the occupational health and safety is to establish a healthy and safe environment for employees and to prevent occupational accidents that may occur due to operational reasons [17, 18, 19]. The objective of this research is to evaluate ergonomics risk assessment by using REBA (Rapid Entire Body Assessment), RULA (Rapid Upper Limb Assessment) and using revised NIOSH (The National Institute for Occupational Safety and Health) lifting equation methods in a logistics company located within the boundaries of Marmara Region, Kocaeli province. Beside the ergonomics risk assessment methods, environmental conditions were measured with calibrated instruments by an accredited laboratory to evaluate personal noise, ambient dust, respirable dust, vibration, chemical and thermal comfort measurements.

MATERIAL AND METHODS

The duration of the study was limited to four months. Before, one month of observation and data collection were carried out. The study was divided into three stages. The first stage consists of understanding and recording working conditions and work processes. The second stage is the decision stage on the risk assessment methodology that is appropriate for ongoing works. Calculations were made by selecting the appropriate risk assessment methodology according to their working postures. The third stage is where the work environment measurements were made by accredited instruments.

First Stage

This study was carried out on 5 work processes in a warehouse with a closed area of 8000 m^2, on a sample area where 57 employees. At this stage, the barcode system and reading devices connected to the system are used. Products are taken to the workplace from the goods receiving area. The goods are read by handheld terminal device and placed on next to the products in the warehouse. The products are prepared to be placed on the shelves determined by the system. The products are read back with the handheld terminal device to determine which shelf to place and move to the specified shelf. Before placing, the number of the product and the shelf are read again with hand held terminal device. The shipping products, determined according to customer requests, are prepared from the products that already placed on the shelves. During the preparation process, the product barcodes are read with handheld terminal device and their locations are determined. The products are collected from certain places and brought to the product preparation yard for shipment. Products are stacked by handling in this area. Labeling is done after the products are stretched. To ensure the order and safety of the products, it is caged with boards. Prepared products are read with handheld terminal device in order to be able to exit the system and they are transported to the loading area for shipment by forklift trucks. Products are shipped after being loaded on the vehicle. Fig. 1 shows the sequence of workflow.

Second Stage

The work of the employees in a logistics warehouse has been identified and photographed. Observed persons and observation time were randomly selected. For risk assessment, as ergonomic risk assessment methods, REBA [20], RULA [21] and NIOSH [22] tools were used and observation was made during working hours. 18 REBA examinations, 9 RULA examinations and 6 NIOSH examinations were conducted during the workflow.

Third Stage

The work environment was measured with calibrated instruments in an accredited laboratory to eliminate

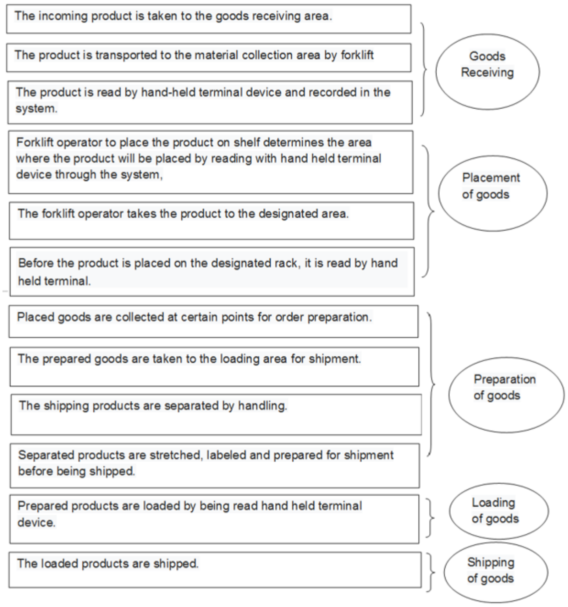

Figure 1. Workflow in logistics warehouse

environmental factors that could affect it. Ambient measurements include ambient noise, personal noise, ambient dust, personal dust, vibration, chemical and thermal comfort measurements. Measurements were carried out for two days, during day and night, together with measurement test personnel. During measurements of daytime, the work done by the employees was also observed in the study.

Thermal comfort measurement was performed according to TS EN ISO 7730 [23]. LASTEM thermal comfort meter was used for the measurements of thermal comfort. Thermal comfort measurements were carried out at 14 points in the working environment.

Ambient noise measurement was performed in accordance with TS EN ISO 11202:2020 [24]. In ambient noise measurements; CASELLA CEL 63X and CASELLA CEL ACOUSTIC CAL devices were used for verification. The measurements were applied in workplaces where compressor and air staple gun are used.

Personal noise measurement was performed according to TS 2607 ISO 1999 [25]. CASELLA CEL 35 and CASELLA CEL Acoustic calibrator were used for personal noise measurements. Personal noise measurements were made at 4 points, including 3 forklift operators and 1 loading personnel.

Vibration measurement was carried out in accordance with the TS EN 1032 + A1 .standard [26]. Measurements were performed with transducers using OKTABA AP-TECH meter for hand-arm and whole-body vibration measurement. . Vibration measurements were made at 3 points, including 2 forklift operators and 1 picker (electric pallet truck) operator.

Measurements of ambient and breathable dust were realized in accordance with TS EN 689 standard [27]. CASELLA CEL TUFF sampling pump was used for the measurements. The system consists of air sampling pump and filter with sampling heads. The system consists of air sampling pump, sampling heads and filter. The sampling pump flow rate was set at 2.2 l/min. Measurements were made for ambient dust measurement at 15 points. Personal dust exposure measurement was carried out on 5 personnel in the workplace.

Chemical substance measurement was performed according to ASTM 1 4490-96 standard [28]. Kitagawa Gas detector tube system AP-20 was used for measurements. Hydrogen, Ethyl Benzene and Xylene gas measurements were made at 3 points in the workplace.

RESULTS AND DISCUSSION

REBA Analyses

After the observations and ergonomic risk assessments made by REBA method in the relevant working area, the studies are presented in Table 1 as follows.

One of the very risky postures (Fig. 2) is selected as an example of the calculations with REBA method (Table 2).

According to the posture of the worker in Fig. 2, trunk is 3 points since it is flexed between 0° – 20° and slightly side flexed (2+1). Neck is 2 points due to the flexion more than 60°. Legs are 3 points since there is unilateral weight bearing and knees between 30° and 60° flexion (2+1), Since the load is greater than 10 kg, the Load/Force score is 2 and the Load/Force score is added to Table A score. Upper arm is 2 points due to the flexion between 20° and 45°. Lower arm 2 points due to flexed less than 60°. Wrist 2 points due to the flexion greater than 15°. The total REBA score is 11, this refers to a REBA action level of 4 indicating a very high risk of injury.

During the preparing product phase, removing the product from the shelf (1), palletizing the product (1), handling for packaging of products (1) procedures (Table 1) are at a high risk level and require immediate action. When removing the product from the shelf, the score can be reduced by improving the posture of the neck, upper arm, lower arm and wrist, primarily the body and leg. When palletizing the product (2), the risk can be reduced by reducing the score with improvements in order of priority; in body, leg, neck and upper arm postures. When handling for packaging of products, the score can be reduced by improving the neck,

Table 1. REBA results.

NO	JOB DESCRIPTION	REBA SCORE	REBA RESULT
1	Read-out with handheld terminal device	2	Low risk
2	Using Picker Forklift (forward)	4	Medium risk
3	Using Picker Forklift (backward)	4	Medium risk
4	Pallet Handling Process	9	High risk
5	Removing the Product from the Shelf 1	11	Very high risk
6	Removing the Product from the Shelf 2	9	High risk
7	Palletizing the Product 1	8	High risk
8	Palletizing the Product 2	11	Very high risk
9	Handling for Packaging of Products 1	9	High risk
10	Handling for Packaging of Products 2	11	Very high risk
11	Cage process 1	5	Medium risk
12	Cage process 2	9	High risk
13	Stretch film packaging processes	9	High risk
14	Labeling process	5	Medium risk
15	Handling process	13	Very high risk
16	Pallet Truck Handling (Towing) Process	9	High risk
17	Pallet Truck Operation (Push) Operation	12	Very high risk
18	Battery charge water filling process	2	Low risk

Figure 2. Removing the product from the shelf 1

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Table 2. REBA evaluation of removing the product from the shelf 1.

	SCORES
Trunk	3
Neck	2
Legs	3
Table A	**6**
Load Force	2
SCORE A	**8**
Upper Arm	2
Lower Arm	2
Wrist	2
Table B	**3**
Coupling	2
SCORE B	**5**
SCORE C	**10**
Activity Score	1
REBA SCORE	**11**

upper arm, lower arm and wrist postures, primarily with the body and leg. In order to reduce the scores, the workers could use equipment such as a high platform or lifting vehicle.

RULA Analyses

Results of RULA method are shown in Table 3 for all working positions.

Reading of the product with the hand held terminal on forklift (Fig. 3) is selected as an example of the calculations with RULA method (Table 4).

According to the scores given to this posture (Fig. 3), upper arm is 2 points, lower arm 3 is points, wrist score is 2 points, wrist rotation is 1 point, neck and trunk postures have 4 points, legs score is 1 point, muscle use is 1 point, force is 0 point. The RULA score was calculated as 7. In order to decrease the scores of the unloading of the vehicle, the use of forklifts is one of the processes, precautions should be taken as soon as possible. The forklift seat should be adjustable and ergonomic. Vehicle seats can be adjusted until reaching the correct position.

The use of Reach Truck (forward) in the product placement process and the re-reading of the product with the hand held terminal in the product placement on the shelf had a very high risk. The values can be decrease by improvements in product placements on the shelf, especially in the lower arm, neck and body postures and in the process of re-reading the product by hand held terminal.

Table 3. RULA results

NO	JOB DESCRIPTION	REBA SCORE	REBA RESULT
1	Vehicle Unloading (forklift operations)	6	Medium risk
2	Reach-Truck Operation (forward)	7	Very high risk
3	Reach-Truck Operation (backward)	5	Medium risk
4	Product reading process with hand held terminal	3	Low risk
5	Reading of the product with the hand held terminal on forklift	7	Very high risk
6	Product Rack Placement Process	6	Medium risk
7	Forklift Operation	3	Low risk
8	Driver's Seating Process	5	Medium risk
9	Cleaning Automat Using Process	6	Medium risk

Figure 3. Reading the product with the hand held terminal on the forklift.

Precautions are also required for the use of Reach-Truck (back) and for placing product on the shelf identified as medium risk. If the neck and trunk postures can be improved at an angle suitable for ergonomic conditions; resulting values can be reduced.

NIOSH Results

Results of the NIOSH method are shown in Table 5 for all working positions.

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Table 4. RULA analysis of the reading of the product with the hand held terminal on the forklift

	SCORES
Upper Arm	2
Lower Arm	3
Wrist	2
Wrist rotation	**2**
SCORE A	4
Muscle use	**1**
Force	0
SCORE C	5
Trunk	4
Neck	**4**
Legs	1
SCORE B	**7**
Muscle use	**1**
Force	0
SCORE D	**8**
RULA SCORE	**7**

One of the very risky postures is selected as an example of the calculations with NIOSH method as in Fig. 4 and Table 6.

In the NIOSH calculations, the lifting index is less than 1.0, indicates that there is no risk during lifting. Therefore, the lifting work should be planned with a lifting index below 1.0. The lift index between 1.0 and 3.0 indicates that the job is risky and requires ergonomic regulation, and above 3.0 point indicates that the lifting has very high risk and also requires ergonomic regulation. According to NIOSH calculations for the "product preparation process", product preparation 1, preparation of products 2 and preparation of products 4 are very risky and should be taken immediate precautions to ensure employee ergonomics. Product preparation 3, preparation of products 5 and preparation of products 6 are risky and necessary precautions should be taken to protect the musculoskeletal. In order to decrease the lifting index values, load must be brought closer to the employee's body. As the load is closer to the employee's body, the horizontal (H) distance value will decrease, thus the horizontal multiplier (HM) value will increase. The height of the place where the product will be placed should be increased. Vertical multiplier (VM) value will decrease as the vertical height increases. When these arrangements are made, the origin and destination lifting index values will be reduced to below 1 and the work will be safer. In addition to that, it is recommended to use mechanical device for the transportation.

Table 5. NIOSH results

NO	JOB DESCRIPTION	Position	Lifting Index (LI) Value	Assessment
1	Product Preparation position 1	Origin	5.49	Very risky
		Destination	7.46	
2	Product Preparation position 2	Origin	7.17	Very risky
		Destination	5.24	
3	Product Preparation position 3	Origin	1.66	Risky
		Destination	2.11	
4	Product Preparation position 4	Origin	3.50	Very risky
		Destination	4.09	
5	Product Preparation position 5	Origin	1.74	Risky
		Destination	1.49	
6	Product Preparation position 6	Origin	2.45	Risky
		Destination	2.12	

Ambient Measurements

Thermal Comfort Measurement: Thermal comfort measurements were performed at 14 points in the work environment. When the calculated PMV and PPD values are compared with the values given in TS EN ISO 7730 standards [23]; 9 points were warm (slightly warm) and 5 points were in the thermal comfort range for employees. As a result of thermal comfort measurements, the highest PPD value of 9 points measured as slightly warm was 48.2 PPD and the highest PPD value of 5 points in the thermal comfort range was 8.12. Taking into consideration the warehouse structure, a ventilation system can be constructed to ensure that all results are within the range of thermal comfort.

Noise Measurement: The compressor and air staple gun were selected for the noise measurement. During routine operations, the noise sound of the work area with the compressor was measured as 83.2 dB and the noise of the area with the air staple gun was measured as 90.8 dB. Personal noise measurements were carried out at 4 different points, including 3 forklift operators and 1 personnel working in loading operation. In the warehouse, first forklift operator measurement result was 86.5 dB, second forklift operator measurement result was 84.4 dB and the third forklift operator measurement result was 77.9 dB. The measured values of compressor and air staple gun exceed the values recommended by the legislation [29]. In order to eliminate the noise in the environment, the working place of the compressor and air staple gun should be changed and placed in an area where nobody works. The existing noise will be reduced by removing it from the work environment. If this cannot be done, the equipment will be placed in the

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Table 6. Revised NIOSH calculation of product preparation position 1

STEP 1 . Measure and record task variables											
		Hand Location (cm)				Vertical Distance (cm)	Aymetric angle (degree)		Frequency rate	Duration	Object Coupling
		Orijin		Destination			Orijin	Destination	Lifts/min	(Hour)	
3L (Object Weight) (kg)	LC (Load Constant) (kg)	H	V	H	V	D	A	A	F		C
10	20	45	35	60	35	0	45	45	8	2-8	Good

STEP 2 . Determination of the multipliers and compute the Recomended Weiight Limits (RWL)		
	RWL=LC·HM·VM·DM·AM·FM·CM	
Orijin	RWL=23*0.57*0.90*1*0.86*0.18*1	=1.82 kg
Destination	RWL=23*0.42*0.90*1*0.86*0.18*1	=1.34 kg

STEP 3 . Computation of the Lifting Index (LI)		
Orijin	$\text{Removal } \% = \left(\frac{C_0 - C}{C_0}\right) x100$	10/1.82 = 5.49
Destination	$\text{Removal } \% = \left(\frac{C_0 - C}{C_0}\right) x100$	10/1.34 = 7.46

Figure 4. RThe product preparation position 1 (a) origin position, (b) destination position.

cabin that absorbs the noise. Even though all the measures are taken and the noise level cannot be reduced below the legal legislative limit, employees should use personal protector equipment.

According to the results of personal noise measurement, high results were obtained in two forklift operators respecting to legal regulations. The measurement results of the other two personnel are below the legally approved values [29]. As a precaution for forklift operators, noise-absorbing apparatus should be used in forklift cabins. In case the noise level cannot be reduced, employees working in places that exceed the noise limit should wear earplugs during operations.

Vibration Measurement: Three points were selected for vibration measurement and the measurement was made on 2 forklift operators and 1 picker operator. First forklift operator's vibration measurement result was 405×10−3 m/s2, second forklift operator's vibration measurement result was 593×10−3 m/s2, and the result of the operator using the crane was 621×10−3 m/s2. The vibration value of first truck operator is below the value recommended by the legislation [30], while the vibration value of other vehicles' operator is higher than legal values. Factors such as the defects on the ground in the warehouse, the working time and the duration of the work, the type and weight of transported product may cause these alterations in the value of the vibration measurements. Necessary precautions should be taken for the exposure above the action limit.. Damaged floors should be amended. Vibration absorbance materials should be used such as sponge, cover, cushion, etc.

Dust Measurement: 15 Points were determined in the work area for ambient dust measurement. Results are as follows: 2.833 mg/m^3, 2.347 mg/m^3, 1.856 mg/m^3, 1.356 mg/m^3, 1.025 mg/m^3, 0.865 mg/m^3, 0.791 mg/m^3, 0.754 mg/m^3, 0.674 mg/m^3, 0.583 mg/m^3, 0.577 mg/m^3, 0.567 mg/m^3, 0.522 mg/m^3, 0.496 mg/m^3, 0.386 mg/m^3. 5 personnel were assigned for individual dust exposure measurement. The results are as follows: 1.867 mg/m^3, 1.546 mg/m^3, 1.071 mg/m^3, 1.049 mg/m^3, 0.862 mg/m^3. The values were below the legal limits [27]. The work environment should be cleaned regularly with a cleaning machine.

Chemical Substance Measurement: Hydrogen, Ethyl Benzene and Xylene measurements were made by selecting 3 different points. Hydrogen was measured in trace amounts, Ethyl Benzene was 1 ppm and Xylene was 25 ppm. Although the results are below the legal limits [31], the standard masks should be used and ventilation are recommended.

CONCLUSION

In this study, REBA, RULA and NIOSH methods were used as ergonomic risk assessment tools. As a result of these analyses, it was identified that there are risky working postures in the wok processes. There is a lot of pushing, pulling, lifting and carrying work in the logistics sector. This study was carried out in order to be an example for detecting and correcting awkward postures in the sector. It is aimed to show the ergonomics science and occupational health and safety discipline must be handled in the logistics' sector in work processes against repeated and inappropriate working postures. In this way, safe working environments can be established with simple-preventive measures for both employers and employees.

Considering the human factor, changes may occur in the consequences of hazards and risks due to the effects such as employee's knowledge, safety culture approach and experience. The measures should be taken at the source of the hazard and the use of human factor will be minimized by making technological improvements such as automation and arranging the products by using machine power. If precautions cannot be taken at the source, the risks should be reduced with engineering measures to be carried out in the environment. Improvements can be made with engineering applications such as safe high platforms, mechanical arms used to take materials.

A collaborative work with the management system is recommended to prevent inappropriate positions and to raise awareness in logistics' sector. In very dangerous workplaces, the training period of an employee is 16 hours according to the legislations [32] in Turkey. Additional ergonomics training is recommended for employees at regular intervals. Training should be prepared by examining inappropriate work experiences and hazards as well as the reason and prevention methods of occupational musculoskeletal disorders. The posture suggestions presented in relation to the activities such as lifting, pushing and pulling movements are valid also to ensure the quality of daily life. Special efforts should be made by occupational physicians and job analysts in order to eliminate or reduce backbone problems. Special work, training, nutrition, rest periods, exercise movements and personalized work plans could be prepared for employees.

Ergonomics science and occupational health and safety discipline must be handled in the logistics' sector in work processes against unwittingly repeated and habitual dangerous behaviors and against inappropriate working postures. In this way, safe working environments can be established with simple and preventive measures for both employers and employees.

ACKNOWLEDGEMENT

The authors would like to thank Assist. Prof. Dr. Esin Tümer Kurnaz for her valuable advice on this project. This article is derived from the Master thesis of Kaan Kırcı at Üsküdar University, Institute of Health Sciences.

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