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Application of RULA and NIOSH Ergonomic Risk Assessment Methods: A Case Study in Construction Industry in Turkey

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***Abstract*—According to occupational health and safety risk assessment regulation in Turkey, the identification of hazards in all workplaces are necessary. A risk assessment should be performed to eliminate the hazard and monitoring control activities in all workplaces. The aim of this study is to analyze the working postures of construction workers and to make ergonomic risk assessments using RULA and NIOSH methods. Furthermore, it is aimed to reveal ergonomic hazards and risks during construction works and to suggest possible prevention ways. Workers in a construction company, which is operating in district Kartal of Istanbul in Turkey and located on the Asian side of the city, is examined and 9 different kinds of construction-related activities are evaluated. RULA method is applied for preparation of plaster mortar, metal cutting, die cutting, roofing, welding, concrete crushing, drilling and plumbing processes. In addition, NIOSH method is used for brick stacking process. The risk scores are evaluated, and prevention measures are recommended to prevent possible injuries.**

Keywords— Ergonomics; Occupational Health and Safety; RULA Application; NIOSH Application; Construction sector)

I. INTRODUCTION

The responsibility of the employer, as indicated in the Risk Assessment Regulation of the Occupational Health and Safety ACT No 6331 Turkey, is to ensure the health and safety of workers, to manage risk in terms of occupational health and safety and to maintaining and improving evaluate. According to Turkish Statistical Institute [1] statistics annual, 7% of the working population in Turkey is employed in construction sector. Thus, the number of people exposed to ergonomic risks is not small to be underestimated in this sector. According to the Social Security Institution [2], occupational diseases of the musculoskeletal system have a ratio of 7.5% among the total occupational diseases. Lower back disorders are the most common problem among musculoskeletal diseases [3]. Awkward back postures, use of vibrating tolls or equipment, and carrying heavy loads are effective in the occurance of low back pain [4]. It was reported that there is a high prevalence of back pain of the workers who have awkward back posture and undertake heavy physical work [5]. Occupational low back pain occurs due to awkward postures during lifting, pushing, pulling, or carrying objects. Eventually, frequent low back pain becomes a common cause of disability [6]. Low back pain is the second most common cause of labor loss after influenza infections in developed countries and is considered the most important factor affecting the decrease in production [7]. The estimated prevalence of low back pain is 5-20% in the USA and 25-45% in Europe [7]. It was reported that the rate of low back pain is higher in blue collar workers than in white collar workers [8]. Schneider and coworkers [9] showed that there are many ergonomic risk factors such as bending, creeping, squatting, kneeling, climbing, standing in balance in construction works. Lowery et al. [10] mentioned that, in their study on 32,081 workers in the construction of Denver International Airport, it was observed that lift assembly operations take the first place among the other operations in terms of lost-work-time and they reported that the employees cannot come to work for an average of 46 days as a result of accidents. Parida and Ray [11] stated that construction workers have a high risk for musculoskeletal disorders, especially with the effect of lifting and carrying heavy loads. Damlund et al. [12], in a survey of semi-experienced construction workers, stated that 65% of workers suffer back pain. Li and Lee [13] determined that the main sources of physical workload among construction workers, are poor posture, repetitive using of various parts of the body, vibration and static standing. Sporrong and coworkers [14] showed that an important part of the works in construction sector is carried out at raised shoulder positions with muscle activity. Various studies have shown a strong relationship between exposure to physical loads such as heavy load lifting, static muscle loading and bad working postures, and increase in musculoskeletal disorders [15, 16]. In 2003, Merlino et al. [17] conducted a study among young construction workers, about half of the workers described the static standing at work is a major problem contributing to musculoskeletal problems. They found that working in the same position for long periods and extreme bending and twisting are among the first three factors leading to musculoskeletal symptoms. Arndt et al. [18] emphasized that common practices such as heavy lifting, repetitive motions increase the risk of injury.

Lee and Han [19] evaluated eight different works that were performed during construction and found that the most common bad postures occur while working by two hands with the arms above shoulder height and also while standing long-term by bending the body, arms and feet. Kulkarni and Devalkar [20] found that among construction workers, awkward lower body postures, repetitive work and bending of wrists forward and back are the most important factors that increase the risk of Cumulative Trauma Disorders on shoulders, knees, feet, wrists and back. Haydarnzhad et al. [21] found that the prevalence of

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work-related musculoskeletal disorders in the knee, wrist, shoulder, waist and feet are high due to joint contact stress, lifting, or carrying heavy items, working with heavy equipment, long working hours and necessity to work fast.

In Turkey, the number of accidents in construction sector [2] and the consequences of these accidents are significant for workers, organizations, society and countries. Thus, occupational safety and health has become a very important issue. Ergonomic factors play a substantial role in body posture and movement like sitting, standing, lifting, pulling and pushing [6].

The goal of this study is to examine the working postures of the workers in the construction works by RULA and NIOSH risk assessment methods and the risk levels were determined accordingly.

II. MATERIALS AND METHODS

The study focused on 9 different kinds of construction related activities. RULA method [22] is used for plaster mortar preparation, metal cutting, die cutting, roofing, welding, concrete crushing, drilling and plumbing processes. Furthermore, NIOSH methods [23] is applied for brick stacking process.

According to the data of the "Kartal Municipality Directorate of Construction License and Inspection Affairs" [24], there are 524 active construction work in Kartal District. The selected company is one of the construction firms. Afterwards, legal permissions are obtained and the postures of the employees are photographed in this construction company, which is operating in district Kartal of Istanbul, Turkey. Photographs are taken only at one construction site. The ergonomic risk analysis methods are carried out by giving numerical values to the body postures of the employee and risk level values are determined.

III. RESULTS

Brick Stacking Process: Within the scope of the construction project, unloading and stacking of bricks process is seen in Fig. 1a. A floor crane is used to carry bricks from the ground level to higher level. The bricks are carried by a crane with basket and unloaded from the basket to the floor and the bricks are stacked on top of each other at horizontal and vertical distances as shown in Fig. 1b.

(a) (b)

Fig. 1. Brick stacking process a) at the origin b) at the destination

Brick stacking process is evaluated by NIOSH method. As a result of the analysis made at the origin and at the destination of the movement; The Lifting Index value (LI) for the origin was calculated as 3.55 and the LI value for the destination was 4.80 (Table 1). Since both values are greater than 3, the procedure is very risky and requires immediate ergonomic improvements. It was observed that the critical factor was the low frequency multiplier (FM) value which is related to the number of work repetitions per minute.

It should not allow the employees to carry more than one bricks at one time during the unloading and stacking of the bricks taken from the basket at the floor. While carrying the bricks, the load should be kept as close to the body as possible and stacking should not be allowed above a certain height. This will relieve the tension in the upper arm. During the heavy working process, the number of repetitions per minute and the total working time of one day should be reduced.

Table 1. NIOSH analysis of brick stacking process up to high elevation

STEP 1. Measuring and recording of task variables											
Object Weight (kg.)		Hand Location				Vertical Distance (cm)	Asymmetric Angle		Frequency rate	Duration (hrs.)	Object couplin g
		Origin (cm)		Destination (cm)			Origin (ºA)	Destination (ºA)	(lifts/min.)		
L(Object weight)	LC(Load Constant)	H	V	H	V	D	A	A	F		C
6	23	3 5	3 0	5 0	15 0	120	60	60	8	2-8	fair

STEP 2. Determination of the Multipliers and Computation of the RWL's		
	RWL=LCxHMxVMxDMxAMxFMxCM	
Origin	RWL=23 x 0.71 x 0.87 x 0.86 x 0.81 x 0.18 x 0.95	**RWL=1.69**
Destination	RWL=23 x 0.50 x 0.78 x 0.86 x 0.81 x 0.18 x 1.00	**RWL=1.12**
STEP 3. Computation of the LIFTING INDEX		
Origin	LI= Object Weight/RWL=6/1.69	**LI=3.55**
Destination	LI= Object Weight/RWL=6/1.12	**LI=5.35**

Preparation of Plaster Mortar Process: Analysis for the preparation of plastering mortar, which is a generally used material for construction works, is evaluated by RULA. In Fig. 2a, the posture of the employee is examined while preparing plaster mortar. The result of RULA analysis is calculated as 7 (Table 2) and this score indicates a high level of risk for the task and requires an immediate intervention. The causal factor for the event is to carry a heavy item, a handheld mixer, during the process by the employee.

During the preparation of plaster mortar, it should be prevented carrying the mixer by the employee manually during the process thus during this process the mixer should be fixed on the bucket and the bucket should be moved by transport systems.

Table 2. RULA Analysis Table

	Plaster Mortar Preparation	**Metal Cutting Process**	**Die Cutting Process**	**Roofing Process**	**Welding Process**	**Concrete Crushing Process**	**Drilling Process I**	**Drilling Process II**	**Plumbing Process**
Upper Arm	3	3	3	4	2	2	4	2	3
Lower Arm	2	2	2	2	2	1	3	2	2
Wrist	2	2	2	2	2	1	2	1	2
Wrist Bending	1	2	2	2	2	1	2	1	2
Table A	4	4	4	4	3	2	5	3	4
Load/force exertion	3	3	1	1	1	3	3	3	1
Score A	7	7	5	5	4	5	8	6	5
Neck	2	2	2	3	2	2	3	2	2
Trunk	3	4	4	3	3	4	2	2	4
Leg	2	2	2	1	1	2	2	1	2
Table B	5	5	5	4	4	5	4	2	5
Load/force exertion	3	3	1	1	1	3	3	3	1
Score B	8	8	6	5	5	8	7	5	6
RULA SCORE	**7**	**7**	**7**	**6**	**5**	**7**	**7**	**6**	**7**

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Fig. 2. a) Plaster mortar preparation process b) Metal cutting process c) Die cutting process d) Roofing process e) Welding process f) Concrete crushing process g) Drilling process-I h) Drilling process-II i) Plumbing process

Metal Cutting Process: The metal cutting process is examined by the RULA method (Fig. 2b) and the score is 7 (Table 2). RULA showed a very high-risk level that would requires immediate intervention. The process is considered critical in the assessment, due to the difficulty caused by the angle between body and legs and also by the weight of grinding machine used in.

Die Cutting Process: Die cutting process is another frequently performed process in construction works and it is examined by RULA method (Fig. 2c). The RULA score is calculated as 7 (Table 2). This score is highly hazardous and requires an immediate intervention. The factor of the event is considered the difficulty caused by the angle between body and legs and as well as the weight of the grinding machine used in. Having suitable work benches for iron cutting and die cutting operations will prevent bending of the employees and prevent strain their waist. In addition, suitability of work equipment for the purpose and the weights of the equipment must therefore be readjusted.

Roofing Process: The roofing process is evaluated by the RULA method (Fig. 2d). The RULA score is calculated as 6 (Table 2). The risk level determined by RULA corresponding to this score includes serious risk level and ergonomic interventions should be developed for roofing areas. Some equipment such as platform and scaffolding should be used in roofing and in all exterior wall coating processes. In welding, the maximum height at which the worker will work without using ladders or scaffolding must be limited. The employee must be positioned in accordance with the procedure.

Welding Process: The welding process is evaluated by the RULA method (Fig. 2e). The RULA score is calculated as 5 (Table 2). This value indicates that the posture is unsecure and requires changes in short time.

Concrete Crushing Process: The concrete crushing process, which is a frequently studied process in the sample area, was evaluated with the RULA method (Fig. 2f). RULA score is calculated as 7 (Table 2). This value shows that the posture is very dangerous and requires immediate change. The weight of the equipment in concrete crushing operations should be easily handled. Also, the load per person should be reduced with auxiliary apparatus. In addition, the total daily working time of the employees and the repetition time per minute should be reduced in repetitive tasks. In repetitive tasks, the number of repeats per minute and the total daily working time should be limited. In addition, it is recommended that the employee should be in a suitable posture according to the working procedure and the drill should be hold closer to chest when drilling.

Drilling Process: The study was evaluated by the RULA method (Fig. 2g and Fig. 2h). The RULA score (Table 2) is calculated as 7 and requires immediate change (Table 1).

Plumbing Process: The Plumbing Process is examined in the sample area by the RULA Method (Fig. 2i). The RULA score is found to be 7 (Table 2). This risk value is very dangerous and requires immediate intervention.

IV. DISCUSSION

In this research, several work postures that arise during construction operations are analyzed by RULA and NIOSH methods and the results are given in Table 3. In large construction projects, materials are constantly being raised from the ground to the upper level by using equipment such as tower cranes and elevators. However, in small scale projects, the process is carried out with floor cranes due to the lack of space for installation of equipment and economic costs.

Table 3. Ergonomic risk analysis: Summary table

Process	Risk Assessment Method	Score	Risk Level
Plaster Mortar Preparation	RULA	7	Very High
Metal Cutting Process	RULA	7	Very High
Die Cutting Process	RULA	7	Very High
Roofing Process	RULA	6	High
Welding Process	RULA	5	High
Concrete Crushing	RULA	7	Very High
Drilling I	RULA	7	Very High
Drilling II	RULA	6	High
Plumbing	RULA	7	Very High
Brick Stacking Process (origin)	NIOSH	2.8	High
Brick Stacking Process (destination)	NIOSH	4.6	Very High

In the stacking process the degree of ergonomic risk increases especially with increasing stack heights. To avoid these situations, it is important to limit the excessive stack heights in machine-free operations.

Mixtures of materials are mainly used as binders in construction projects. According to the Earthquake Regulation issued in 2000 after the Kocaeli Earthquake, concrete mixtures must be taken from ready-mixed concrete plants. However, the preparation of the plaster mixtures is still carried out within the construction site and prepared by workers. Depending on the amount of plaster mortar to be used, this process can be done with mixers called concrete mixers, but in residential construction projects where the amount of use is low, this process is carried out entirely with manpower. In Table 2, the risk analysis of the plaster mortar preparation process is carried out by using the RULA method and the risk is found to be very high and requires urgent improvement. The main reason of the high risk is that the hand-held mixers which are carried by the workers throughout the process, during the preparation of plaster mortar. The main material used in construction works is the concrete and then second one is the steel which is one of the strongest building materials available with excellent strength capacity in both tension and compression; for this reason it is used especially in construction of carrier systems. Steel is one of the most used raw materials by construction workers. The steel is delivered to the construction sites with the required diameters and as a standard 12-meter rod. These rods are cut, shaped and connected to the desired dimensions in the iron installed benches at the construction site. In particular, other steel bars except the carrier systems are prepared after, to be used outside as they cannot be prepared in advance. Due to the lack of iron workbenches, the worker who needs steel usually tries to cut the steel with the circular saw in his hand and can use any environment for this process. The score obtained at RULA method is found to be 7 as can be seen in Table 3 and this value was classified as very high risk.

The materials used as molds are generally made of wood, metal, etc., in order to preserve the shape of the flowing concrete until it becomes dry and hard, during the formation of the concrete carrier system. Since such materials are suitable for cutting, especially the wooden ones, they are cut on construction sites and used in suitable processes. After the completion of the carrier system, the wood benches are moved away from the construction site and the wood cutting process is done in awkward positions. While the employee is cutting the wood material in an inappropriate way, the RULA score is classified as very dangerous and implement change is needed.

Exterior wall surfacing is generally done with the help of scaffolding or platforms, although in minor construction projects or renovation projects enough equipment is not used for this job. In this process, the posture of the employee who makes roofing with wooden formwork material has been analyzed by RULA Method and the risk is found high and required immediate change.

Welding is a method commonly used for joining two metals. There are many physical and chemical risk factors involved in the process thus the process has ergonomic risks. In the sample area, the risk assessment of an employee was performed during welding two metals. The conditions under which welding is carried out are considered as the main factor in the risk assessment. The posture of the employee during the joining roof shed had a direct impact on the outcome of the risk assessment. Table 3 presents the results of the risk analysis performed by the RULA method during welding. It was found that the score is high and the process requires further investigation and an immediate change.

In construction projects, the carrier system is designed scientifically and by statutory calculations as prescribed by law. It is a legal obligation that the application of the design be fully compatible with the design project. However, especially in housing projects, unlawful changes are made in the constructions due to the demands of the end user and also the financial concerns of the contractor. In addition, if there is a construction section that is sometimes built accidentally, it is occasionally necessary to change some units of the construction. These modifications can be made especially by breaking the concrete. Although the reason for the concrete breaking process is not questioned but in-place evaluation was done for the posture of the worker during this process as the main risk factor. The RULA score is classified as very high and requiring immediate correction.

The drill and drilling work is present in all construction projects. In the sample area, two different tasks are evaluated during working with drill. The body posture of the employees during the use of drill is analyzed. Especially the elevation difference between where the drill is used and where the employee is located and the ways of holding the drills are determinative in the risk score. The results that are obtained from the evaluation of working with two different drills are seen at the Table 2 and examined by the RULA method as high risk and requiring immediate modification.

Especially in housing projects, the electricity, water, gas, telephone and similar needs are provided inside the building. These works have to be carried out in confined spaces and under adverse circumstances. According to RULA score during the plumbing process it is seen that the work is classified as very high risk and requires immediate implement changes.

Consequently, the obtained scores in all risk assessments are high scores and risk levels are classified as high or very high risk levels.

V. CONCLUSION

In this study, the postures of the workers in the construction works are analyzed by RULA and NIOSH risk assessment methods and some suggestions are given as follows:

i. Explaining ergonomics and related risk factors and methods of protection from these risks will be beneficial to raise awareness of employees in occupational health and safety trainings even for longer time.

ii. Ensuring that lifting operations are performed by using appropriate machinery (platform, pallet crane, etc.) not only in construction works but also in all sectors; it is important in terms of preventing all risks, especially ergonomic risks. In that case, it is recommended to adopt an applicable regulation on lifting loads on safe weight limits.

iii. It should be ensured that the materials on which manually handling is required should be limited such as brick, cement bag, aerated concrete and so on. The relevant materials in the manufacturer should be packaged in such a weight that the employee can safely handle them.

iv. Beside the limiting material weights, the material stacking heights must be limited for each material stacked by hand. In addition to material strength, ergonomic working conditions of the manual stacker must be taken into account

v. Generally, employees in construction sector do not know how to work by proper and healthy posture. The most important reason for this situation is inadequacy of health and safety education in Turkey. For this reason, it is recommended to apply the occupational health and safety education to pre-school institutions and to raise awareness of individuals starting from childhood ages in this subject.

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