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Integrated Ergonomic Risk Analysis by Using REBA, RULA, OWAS, and AHP in the Furniture Manufacturing Line

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Abstract: Ergonomic risk is defined as the existence or potential of factors that may negatively affect the health and safety of employees in the workplace. The main source of ergonomic risks may be unsuitable working body posture, carried loads or applied forces at the workplaces. In order to protect employee health, ergonomic risk assessments must be carried out in workplaces to determine risk levels and take necessary precautions. This study was carried out in a company that produces furniture in the furniture sector. 42 working postures were evaluated in the study. Ergonomic risk levels of employees were determined by using REBA, RULA, OWAS and MURI methods. Since the risk score levels of each of these methods are different, the AHP method was applied to obtain an integrated risk score. Risk values were ranked using the criteria weights determined by the AHP method. While applying the AHP method, 3 decision makers were employed. Decision makers compared each ergonomic risk assessment method and determined their importance levels. According to the integrated risk scores, the highest risk levels of operations were determined to be taping the box (58%), sewing (45%), putting the finished parts (43%), removing the feet (43%), closing the box lids (42%) and removing the bases of parts (40%), respectively, and necessary remedial suggestions were presented.

Keywords: Ergonomics, risk Analysis, REBA, RULA, AHP

Öz: İşyerlerinde çalışanların sağlığını ve güvenliğini olumsuz etkileyebilecek faktörlerin varlığı veya potansiyeli ergonomik risk olarak tanımlanmaktadır. İşyerlerindeki ergonomik risklere, uygun olmayan vücut pozisyonları, taşınan yükler veya uygulanan aşırı ve sık tekrarlı kuvvetler gibi vb. unsurlar neden olabilir. Çalışan sağlığını korumak için işyerlerinde gerekli ergonomik risk değerlendirmeleri yapılmalı, olası risk seviyelerinin tespit edilerek ve gerekli önlemlerin alınması sağlanmalıdır. Bu çalışmada, mobilya sektöründe üretim yapan bir işletmede üretim süreçleri dikkate alınak çalışanların ergonomik risk seviyeleri REBA, RULA, OWAS ve MURI yöntemleri belirlenmiştir. Bu yöntemlerin her birinin risk skorları farklı olduğundan bütünleşik sonuç elde edebilmek için AHP yöntemi uygulanmıştır. AHP yöntemi ile belirlenen kriter ağırlıkları kullanılarak sıralama yapılmıştır. AHP yöntemi uygulanırken 3 karar verici ile çalışılmıştır. Karar vericiler her bir ergonomik risk değerlendirme yöntemlerini ikili olarak karşılaştırarak birbirlerine göre önem düzeyleri belirlenerek yüksek risk düzeyine sahip süreçler tepit edilmiştir. Bütünleşik risk skorlarına göre en yüksek riske sahip işlemlerin sırasıyla kutuyu bantlama (%58), dikim işlemi (%45), biten parçaları kenara koyma (%43), ayakları alma (%43), kutunun kapaklarını kapatma (%42) ve altlıkları alma (%40) şeklinde olduğu belirlenerek gerekl iyileştirici öneriler sunulmuştur.

Anahtar Kelimeler: Ergonomi, risk Analizi, REBA, RULA, AHP

1. Introduction

Machines have become widely used in today's production system. Although mechanization and automation increase the speed of production, the need for physical manpower is present in many areas. Especially in businesses with labor-intensive production system, employees are faced with intense musculoskeletal system disorders (MSDs). MSDs is one of the most common health problems in the world. This disease occurs in joints, discs, muscles, ligaments, nerves and tendons while performing ordinary body movements such as bending, straightening, holding, grasping, twisting and reaching [1]. According to the Global Burden of Disease results, it has been reported that MSDs increased by 38.4% from 1990 to 2007 and by 19.9% from 2007 to 2017 in 195 countries examined. MSD accounts for 50% of new cases in work-related diseases. In Turkey, MSD ranks second in disability-adjusted life years lost with 37% [2]. These disorders generally result from physical and environmental factors such as repetitive movements, incorrect body postures, static working conditions, excessive workload, and heavy lifting in the workplace [3]. MSD develops over time and mostly affects the upper body parts (such as neck, shoulder, elbow, wrist and waist). This situation causes fatigue, pain and eventually work accidents in the employee and reduces the labor productivity of factory [4]. Improving working conditions is very important for employee health and workforce productivity. The most important way to prevent MSDs is to determine ergonomic risks in the workplace. Ergonomics is an interdisciplinary branch of science that establishes a relationship between employees and working conditions. Ergonomics seeks solutions on how to organize the work environment and adapt it to workers in order to eliminate health problems caused by work and increase productivity [5]. As a result of ergonomic risk assessment analyses, risk scores and the improvements to be made in working conditions are determined accordingly [6]. There area many methods used to assess ergonomic risks. These methods are designed by considering the posture of the worker or the nature of the work. For this reason, it is important to choose the appropriate methods for the job [7].

Beliveau et al. [8] presented a web-based survey study that revealed the level of awareness levels of about MSD risk assessment tools in Canada. Zengin and Asal [9] analyzed 39 working postures of construction industry workers with 3 different ergonomic risk assessment methods suc as REBA, OWAS and QEC. As a result of this analysis, it was seen that the results of the QEC method were different from the other methods. Hawari et al. [10] conducted ergonomic risk analysis with QEC and REBA methods for cutting, lifting and assembly operations in three woodworking workshops. Erginel et al. [11] examined the work postures of workers in a furniture factory with the Fuzzy REBA method. Ekinci and Can [12] analyzed work postures using the REBA method in a fruit juice production line and determined ergonomic risk levels. Akalp et al. [13] analyzed the work postures of agricultural workers during olive harvest with the REBA method and offered some solutions for risky processes. Koç and Testik [14] analyzed 40 tasks in modular and upholstery units of a furniture manufacturing factory with the REBA method. Polat et al. [15] evaluated 32 working postures in a furniture factory with REBA, identified high-risk jobs, and they made recommendations to reduce the identified risks. Costa et al. [16] conducted an ergonomic analysis of an industrial kitchen. In this context, the most critical activities were analyzed with RULA, REBA and OWAS methods and the results were compared. Kahya et al. [17] analyzed 20 different processes performed by using the REBA, NERPA, QEC, OWAS and MURI methods in a company which produces metal parts. According to risk scores they suggested to remedial developments for the first 5 processes with the highest integrated risk scores. Delice et al. [18] performed ergonomic risk assessment analyses with REBA, OWAS, QEC and MANTRA methods in a tube production factory and obtained an integrated result with the AHP method.

In the literature, various analyses have been conducted for ergonomic risk assessment in many different sectors such as textiles, furniture, metal, manufacturing, and construction. It has been observed that methods such as REBA, RULA, NISOH, OCRA, QEC, NERPA, ManTRA, and OWAS are commonly used in the differents manufacturing area. It has also been noted that different methods used for the same tasks in different working conditions may occurred different results. In this case, determining integrated risk scores is important in evaluating the same processes. In this study, it was aimed to determine the integrated risk scores of 42 working postures that can represent the all-production processes, especially in a labor-intensive furniture production, using REBA, RULA, OWAS, MURI and AHP methods. As a result of the analyses, the risk scores for each position of body posture were determined, and risk score weights were established by using the AHP method, considering the views of three decision-makers. Detailed examinations were conducted for the job position with the highest risk score, and ergonomic improvement suggestions were developed.

2. Material and Method

2.1. Material

This study was carried out in a furniture manufacturing company with labor-intensive production. The company is located in the Black Sea Organized Industrial Zone. The product group that is most produced in the company for risk analysis was called as the name A. The production processes of product A consist of 7 steps. These steps can be listed as face fabric sewing, frame laying, polyurethane sponge laying, lining, assembly, foot attachment and packaging. The movements of the workers working at each stage were examined and ergonomic risk analysis was performed according to the REBA, RULA, OWAS and MURI methods. In addition, since the risk scores of each of these methods may give different results, the AHP method was applied in order to obtain an integrated result. Decision makers were selected from experts who have sufficient knowledge about the risk assessment methods used in the study, such as REBA, RULA, OWAS and MURI, as well as the AHP method and the production processes to be examined in the study. Table 1 shows the ergonomic risk assessment method, risk scores and action cases.

Table 1. Risk scores and action statuses depending on risk methods.

Technique	Risk Score	Action
REBA [19]	1	No action required
	2-3	Modification may be needed
	4-7	Further investigation may be needed
	8-10	Modification is required
	>11	Modification is required immediately
RULA [20]	1-2	No action is needed.
	3-4	Measures should be taken, but not in the short term.
	5-6	Measures should be taken in the short term.
	7+	Urgent action must be taken.
OWAS [21]	1	No action required
	2	Ergonomic arrangement should be done soon
	3	Ergonomic arrangement should be done soon
	4	Ergonomic arrangement should be done immediately
MURI [22]	0-10	Green
	11-15	Yellow
	16+	Red

2.2. Analytic Hierarchy Process (AHP)

The AHP method is a Multi-Criteria Decision-Making (MCDM) method that assists decision-makers by providing results that are easy to understand and reliable. This method enables the numerical ranking of alternatives and criteria and contributes to solving complex problems. Problems to be solved using the AHP method should be defined in as much detail as possible and structured according to a specific priority hierarchy. At the top level of the hierarchy is the main goal, while at the lowest level are the decision alternatives [23]. The AHP method generally consists of certain stages, which are detailed below.

Building the hierarchical model: At the top is the main goal to be achieved, while the criteria used to reach this goal are located at the middle level. At the lowest level are the alternatives evaluated in the decision-making process. An example of a three-level hierarchical structure is provided in Figure 1.

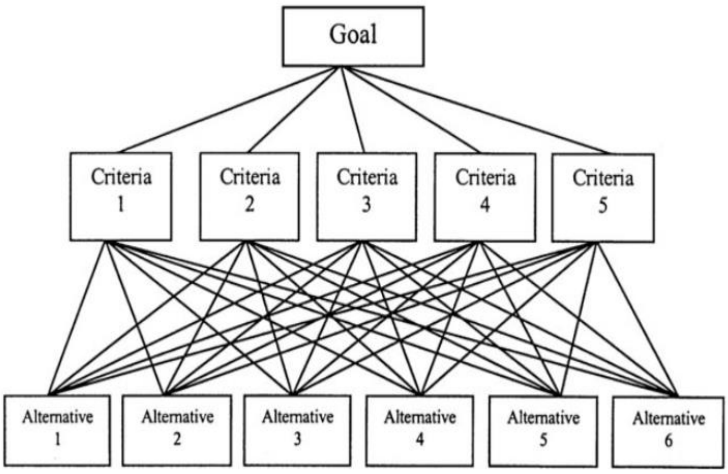

Figure 1. Example AHP model

Preparation of Pairwise Comparison Matrices: After building the hierarchical model, pairwise comparison matrices are prepared to determine the relative importance of each element. In these matrices, decision-makers determine the importance levels for each pair. When criterion i is compared with criterion j, the 1-9 scale proposed by Saaty [24] is used to determine the degree to which criterion i is preferred over criterion j. This comparison scale is provided in Table 2.

Table 2. Comparison scale of AHP method

Severity Level	Definition	Explanation
1	Equal importance	Two activities have equal contribute to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	Sometimes one needs to interpolate a compromise judgment numerically

With the judgments converted into numerical values by means of the comparison scale, the pairwise comparison matrix, whose general representation is provided in Equation 1, is constructed.

$$\boldsymbol{A_{ij}} = \begin{bmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \cdots & \boldsymbol{a_{1n}} \\ \boldsymbol{a_{21}} & \boldsymbol{a_{22}} & \cdots & \boldsymbol{a_{2n}} \\ \boldsymbol{a_{n1}} & \boldsymbol{a_{n2}} & \cdots & \boldsymbol{a_{nn}} \end{bmatrix} \quad (1)$$

Pairwise comparisons are made for the upper triangular part of a matrix whose diagonal elements are equal to 1. That is, the diagonal elements of A (a_{ij}) must take the value of 1. If A_{ij} represents the pairwise comparison value of criterion *i.* and *j.* then A_{ij} is obtained by the equality $A_{ij} = 1/A_{ij}$.

To make decisions using the AHP method, the comparison matrix *A*, which is formed in the case where *n* criteria exist, will have a size of $n \times n$. If there is more than one decision-maker, the pairwise comparison matrices must be transformed into a single pairwise matrix using the geometric mean method. Therefore, the comparison of criterion *i* and criterion *j* by decision-maker kk is expressed as a_{ij}^k, and the common decision regarding the criterion made by *n* decision-makers is transformed into a single pairwise comparison matrix using the geometric mean method with the formula given in Equation 2.

$$\boldsymbol{a_{ij}^k = (a_{ij}^1 * a_{ij}^2 * \ldots .* a_{ij}^n)^{1/n}} \quad (2)$$

Calculation of the normalized pairwise comparison matrix: The values in the initial A_{ij} matrix, which is prepared based on the judgments of the decision-makers, are determined as numbers between 0 and 1 using Equation 3.

$$\boldsymbol{b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}} \quad (3)$$

This operation is performed by dividing each element of the initial A_{ij} matrix by the sum of its respective column. This process is repeated for each column. The new matrix obtained is the normalized pairwise comparison matrix N_{ij} , as shown in Equation 4.

$$\boldsymbol{N_{ij}} = \begin{bmatrix} \boldsymbol{b_{11}} & \boldsymbol{b_{12}} & \cdots & \boldsymbol{b_{1j}} \\ \boldsymbol{b_{21}} & \boldsymbol{b_{22}} & \cdots & \boldsymbol{b_{2j}} \\ \boldsymbol{b_{i1}} & \boldsymbol{b_{i2}} & \cdots & \boldsymbol{b_{ij}} \end{bmatrix} \quad (4)$$

Calculation of the Weight Matrix: The b_{ij} values in the normalized matrix obtained in Step 3 are averaged row-wise using the formula in Equation 5.

$$\boldsymbol{W_i = \frac{\sum_{j=1}^{n} b_{ij}}{n}} \quad (5)$$

The obtained values for each row form the weight matrix W_i , as shown in Equation 6. The W_i matrix represents the percentage importance distribution of the criteria.

$$\boldsymbol{W_i} = \begin{bmatrix} \boldsymbol{W_1} \\ \boldsymbol{W_2} \\ . \\ \boldsymbol{W_n} \end{bmatrix} \quad (6)$$

Performing Consistency Test Procedures: The matrices formed by decision-makers must be consistent. Here, consistency refers to the mutual compatibility of the pairwise comparisons of criteria and alternatives. If Equation 7 is satisfied for all *i, j, k* it indicates that the pairwise comparison matrix *A* is consistent.

$$a_{ij} * a_{jk} = a_{ik} \quad (7)$$

As a result, the matrix *N*, where all rows and columns will be equal in the pairwise comparison matrix *A* accepted as consistent, is calculated as shown in Equation 8.

$$\boldsymbol{N} = \begin{bmatrix} \boldsymbol{W_1} & \boldsymbol{W_1} & \boldsymbol{W_1} \\ \boldsymbol{W_2} & \boldsymbol{W_2} & \boldsymbol{W_2} \\ \boldsymbol{W_n} & \boldsymbol{W_n} & \boldsymbol{b_{ij}} \end{bmatrix} \quad (8)$$

After this stage, the symmetric matrix *A* is obtained by dividing the elements in the iii-th column of the matrix *N* by W_i. Thus, the matrix given in Equation 9 is obtained.

$$\boldsymbol{A} = \begin{bmatrix} \boldsymbol{1} & \boldsymbol{W_1/W_2} & \cdots & \boldsymbol{W_1/W_n} \\ \boldsymbol{W_2/W_1} & \boldsymbol{1} & \cdots & \boldsymbol{W_2/W_n} \\ \vdots & \vdots & \vdots & \vdots \\ \boldsymbol{W_n/W_1} & \boldsymbol{W_n/W_2} & \cdots & \boldsymbol{1} \end{bmatrix} \quad (9)$$

By continuing with the definition of *A*, the matrix provided in Equation 10 is obtained.

$$\begin{bmatrix} 1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & 1 & \cdots & W_2/W_n \\ \vdots & \vdots & \vdots & \vdots \\ W_n/W_1 & W_n/W_2 & \cdots & 1 \end{bmatrix} * \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ \vdots \\ W_n \end{bmatrix} = \begin{bmatrix} n*W_1 \\ n*W_2 \\ n*W_3 \\ \vdots \\ n*W_n \end{bmatrix} = n * \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ \vdots \\ W_n \end{bmatrix} \quad (10)$$

In summary, *A* can only be considered consistent if the equation given in Equality 11 is satisfied.

$$A * w = n * W \quad (11)$$

The *w* w_i in Equation 11 represents the column vector of relative weights for $i= 1,2,3,\ldots n$. Moreover, when the size of the normalized pairwise comparison matrix given in Equation 4 is greater than 2×2 , the column values of the relevant matrix can be checked to determine whether the matrix is identical. As a result of this check, if there is a normalized pairwise comparison matrix where the column values are identical, the relative importance weights will remain the same regardless of how the pairwise comparison was conducted, and a consistency test will not be necessary. The A_{ij} matrix given in Equation 1 and the W_i weight matrix given in Equation 6 are multiplied according to the rules of matrix multiplication (as per Equation 11). The column sums of the resulting matrix represent the n_max value [23] (Karaburun, 2018). If the despite all the checks, the equality in the columns of the normalized pairwise comparison matrix specified in Equation 4 is not achieved, the CR (Consistency Ratio) is calculated using the formula shown in Equation 12.

$$CR = \frac{CI}{CR} \quad (12)$$

The *CI* in Equation 12 is the Consistency Index, and RI is the Random Index. The calculation of *CI* and *RI* is carried out using the formulas in Equations 13 and 14.

$$CI = \frac{n_{max} - n}{n - x} \quad (13)$$

$$RI = \frac{1{,}98(n-2)}{n} \quad (14)$$

In the calculation of *CR*, the Random Index (*RI*) table, which contains fixed values based on the number of criteria (*n*) used in the pairwise comparison, is provided in Table 3.

Table 3. Random Indices

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.6	0.9	1.1	1.2	1.3	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6

After calculating the CR value, some comments can be made based on the result. These are: If $CR \leq 0{,}1$ it can be said that the consistency level of the pairwise comparison matrix *A* is at an acceptable level.

If $CR > 0{,}1$ it is understood that the consistency level of the pairwise comparison matrix *A* is not at an acceptable level. In the case of inconsistency, the decision-maker needs to review their judgments, reconstruct the pairwise comparison matrix *A*, and repeat the process.

3. Findings and Discussion

3.1. Findings on Classical Risk Scores

When the literature is reviewed, it is seen that methods such as REBA, RULA, OWAS, and MURI have been successfully applied in various sectors. Some of these studies include; Akay et al. [3] conducted a risk analysis using the OWAS method in auto-service stations and proposed corrective recommendation, Atıcı et al. [25] conducted a risk analysis using the REBA method in a cable manufacturing facility, Ülker and Buldurlu [26] performed measurements using the OWAS method in a furniture enterprise and identified risk values, Kahraman [27] conducted analyses in a marble enterprise using REBA, RULA, and AHP methods; and in a study by Kılıç Delice et al. [28], ergonomic risk assessments were carried out using REBA, OWAS, QEC, and MANTRA methods in a tube production enterprise categorized as heavy and hazardous work. In the literature, there are various methods with different characteristics for evaluating ergonomic risks. These methods are generally designed to assess the worker's posture (changes in joint positions) during work. It is crucial to select the appropriate method for the specific job while evaluating ergonomic risks [7]. The enterprise where the ergonomic risk analyses were conducted is a furniture manufacturing company located in the Karadeniz Organized Industrial Zone. For the risk analysis, the most commonly produced product group in the enterprise has been anonymized under the name Product A. The production processes for Product A consist of seven main stages: sewing the fabric cover, upholstering the frame, foam padding, lining, assembly, attaching the legs, and packaging. In each production process (including sub-processes), workers' movements were examined, and ergonomic risk analyses were performed using the REBA, RULA, OWAS, and MURI methods. The results obtained are presented in Table 4.

Table 4. Risk scores of operations according to methods

Process	Process steps	REBA	RULA	OWAS	MURI
Sewing the face fabric	(1) Reach for the part	3	3	1	10
	(2) Sewing	5	4	2	11
	(3) Cutting	4	4	1	11
	(4) Reach for the machine	4	3	1	9
	(5) Drop the part	3	3	1	10
	(6) Change the thread and spool	2	4	1	9
Sponge laying	(7) Take the sponges	4	3	1	12
	(8) Take the bases	3	4	2	12
	(9) Reach for the glue gun (600gr)	2	3	1	10
	(10) Apply glue	3	3	1	10
	(11) Put down the glue gun	1	3	1	9
	(12) Stick the base to the sponge	3	3	2	11
	(13) Put the finished items aside	3	3	2	12
Priming / lining	(14) Take the sponge	4	3	1	11
	(15) Adjust the primer lining	2	3	1	12
	(16) Reach for the scissor	3	3	2	11
	(17) Cut the primer lining material	3	3	2	10
	(18) Reach for the stapler	3	3	2	9
	(19) Stapling	4	3	2	10
	(20) Reach for the knife	3	4	2	10
	(21) Open the mechanism	3	2	2	9
	(22) Put the finished items aside	3	3	2	10
Framework laying	(23) Take the frame	3	3	1	10
	(24) Take the cover	3	3	2	9
	(25) Put on the cover	3	3	1	10
	(26) Fix of the cover	5	3	1	11
	(27) Put the finished parts in the box	3	2	2	10
Wheel fitting	(28) Bring the materials to the table	3	2	1	10
	(29) Attach the wheel	4	2	1	9
	(30) Take the hub ring	3	3	2	12
	(31) Install the hub ring	4	2	2	9
	(32) Put the finished parts aside	5	4	1	9
Assembly process	(33) Take the bottom cover	1	4	1	9
	(34) Assemble the bottom cover	4	3	2	11
	(35) Take the mechanism	1	2	1	9
	(36) Assemble the mechanism	4	3	2	10
	(37) Leave the finished ones in the box	2	3	2	10
Packaging	(38) Take the legs	6	3	2	13
	(39) Put the legs in the box	4	3	2	11
	(40) Install the shock absorber	4	4	2	9
	(41) Close the box lids	6	3	2	10
	(42) Tape the box	7	5	2	13

As seen in Table 4, the highest risk level, according to the REBA and RULA methods, is the box taping process (scores of 7 and 5), while according to the MURI method, the box taping and foot retrieval processes have the highest risk (score of 13). According to the OWAS method, 23 processes have the highest equivalent score.

For processes with medium and higher risk levels:

The REBA method identified 17 processes,

The MURI method identified 15 processes,

The RULA method identified 1 process,

The OWAS method identified no processes with medium or higher risk.

As is known, improvements should be made for medium-level risks, while for high-risk levels, improvements are recommended to be made as soon as possible. In ergonomic risk assessment, when different methods are used, different risk scores can be obtained even for the same processes. Therefore, it is important to use a method that is suitable for the work processes or to determine integrated risk scores obtained from multiple methods.

3.2. Results on Determining Risk Scores as Percentages (%)

The structure of each ergonomic risk assessment method used in practice is different from one another. (For example, the maximum risk score in the OWAS method is 4, while it is 15 in the REBA method.) To express risk scores in a common language, they can be converted to the same unit. For this, the percentage (%) value per 1 unit of risk score can be determined. For example, for the RULA score, since the maximum risk score is 7, the value for 1 risk score is calculated as 14.30% (Table 5).

Table 5. Comparison scale

Method	Mak.Score	Score (%)
REBA	15	6.70
RULA	7	14.30
OWAS	4	25
MURİ	27	3.7

In this case, for Process 1 (the reaching movement for the part), the risk scores in percentage (%) terms would be calculated as 20.10% (3x6.7) for REBA, 42.90% (3x14.30) for RULA, 25% (1x25) for OWAS and 37% (10x3.7) for MURI.

If it is assumed that the integrated risk scores of the four methods used have an equal impact (equal weight of 25%), the risk score of Process 1 (the reaching movement for the part) would be calculated as approximately ~%31 [%25. (%20,10+ %42,90+ %25+ %37)] it would have been calculated as. According to this calculation, the integrated risk scores of all movements are given in Table 6.

Although ergonomic risk assessment methods consider body posture and positioning when identifying risks in work processes, the evaluation procedures and risk score classifications of each method differ. In other words, when the same work processes are evaluated using different methods, they may yield risk levels with varying priorities. Sometimes, to obtain more consistent risk scores in the analyzed work processes, an integrated risk score can be calculated by using multiple methods.

Under the assumption that the impact of the methods on the integrated risk score is considered equal, it is assumed that each method has the same influence. However, this assumption may not be consistent due to the differing criteria considered by each risk analysis method. Therefore, obtaining an integrated risk score by weighting each method according to decision-makers' evaluations would provide more reliable results. In this study, the ergonomic risk assessment methods used were weighted using the AHP (Analytic Hierarchy Process), and integrated risk scores were obtained.

Table 6. Integrated risk scores in the case where the weights of methods are assumed to be equal

Process	Process steps	REBA	RULA	OWAS	MURI	REBA%	RULA%	OWAS %	MURI %	Risk Skoru%
Sewing the face fabric	(1) Reach for the part	**3**	**3**	**1**	**10**	**20**	**43**	**25**	**37**	**31**
	(2) Sewing	5	4	2	11	34	57	50	41	45
	(3) Cutting	4	4	1	11	27	57	25	41	37
	(4) Reach for the machine	4	3	1	9	27	43	25	33	32
	(5) Drop the part	3	3	1	10	20	43	25	37	31
	(6) Change the thread and spool	2	4	1	9	13	57	25	33	32
Sponge laying	(7) Take the sponges	4	3	1	12	27	43	25	44	35
	(8) Take the bases	3	4	2	12	20	57	50	44	43
	(9) Reach for the glue gun (600gr)	2	3	1	10	13	43	25	37	30
	(10) Apply glue	3	3	1	10	20	43	25	37	31
	(11) Put down the glue gun	1	3	1	9	7	43	25	33	27
	(12) Stick the base to the sponge	3	3	2	11	20	43	50	41	38
	(13) Put the finished items aside	3	3	2	12	20	43	50	44	39
Priming or lining	(14) Take the sponge	4	3	1	11	27	43	25	41	34
	(15) Adjust the primer lining	2	3	1	12	13	43	25	44	31
	(16) Reach for the scissor	3	3	2	11	20	43	50	41	38
	(17) Cut the primer lining material	3	3	2	10	20	43	50	37	38
	(18) Reach for the stapler	3	3	2	9	20	43	50	33	37
	(19) Stapling	4	3	2	10	27	43	50	37	39
	(20) Reach for the knife	3	4	2	10	20	57	50	37	41
	(21) Open the mechanism	3	2	2	9	20	29	50	33	33
	(22) Put the finished items aside	3	3	2	10	20	43	50	37	38
Framework laying	(23) Take the frame	3	3	1	10	20	43	25	37	31
	(24) Take the cover	3	3	2	9	20	43	50	33	37
	(25) Put on the cover	3	3	1	10	20	43	25	37	31
	(26) Fix of the cover	5	3	1	11	34	43	25	41	36
	(27) Put the finished parts in the box	3	2	2	10	20	29	50	37	34
Wheel fitting	(28) Bring the materials to the table	3	2	1	10	20	29	25	37	28
	(29) Attach the wheel	4	2	1	9	27	29	25	33	28
	(30) Take the hub ring	3	3	2	12	20	43	50	44	39
	(31) Install the hub ring	4	2	2	9	27	29	50	33	35
	(32) Put the finished parts aside	5	4	1	9	34	57	25	33	37
Assembly process	(33) Take the bottom cover	1	4	1	9	7	57	25	33	31
	(34) Assemble the bottom cover	4	3	2	11	27	43	50	41	40
	(35) Take the mechanism	1	2	1	9	7	29	25	33	23
	(36) Assemble the mechanism	4	3	2	10	27	43	50	37	39
	(37) Leave the finished ones in the box	2	3	2	10	13	43	50	37	36
Packaging	(38) Take the legs	6	3	2	13	40	43	50	48	45
	(39) Put the legs in the box	4	3	2	11	27	43	50	41	40
	(40) Install the shock absorber	4	4	2	9	27	57	50	33	42
	(41) Close the box lids	6	3	2	10	40	43	50	37	43
	(42) Tape the box	7	5	2	13	47	72	50	48	54

3.3. Results of the AHP Method

The AHP method was applied with the involvement of three decision-makers. The decision-makers conducted pairwise comparisons of each ergonomic risk assessment method to determine their relative importance.

The pairwise comparison matrices created by the decision-makers were combined using the geometric mean. The Combined Decision Matrices of the three decision-makers are presented in Table 7, and the Normalized Matrices are presented in Table 8.

Table 7. Combined Decision Matrices

Method	REBA	RULA	OWAS	MURİ
REBA	1.000	0.693	7.612	4.217
RULA	1.442	1.000	3.557	4.932
OWAS	0.131	0.281	1.000	0.523
MURİ	0.237	0.203	1.913	1.000
Total	2.811	2.177	14.081	10.672

Table 8. Normalized Matrix

Method	REBA	RULA	OWAS	MURI
REBA	0.356	0.318	0.541	0.395
RULA	0.513	0.459	0.253	0.462
OWAS	0.047	0.129	0.071	0.049
MURI	0.084	0.093	0.136	0.094

The combined priority weights of the four methods used were calculated, and these calculated values are presented in Table 9.

Table 9. Combined with priority values (Weights) (%)

Method	Values of weight (%)
REBA	40.2
RULA	42.2
OWAS	7.4
MURI	10.2

The consistency ratio was determined to be 0.054. Since this value is less than 0.1, the matrix is considered consistent. While coefficients in mathematical programming problems are explicitly known, in real-world business operations, coefficients are not always numerically defined. In such cases, efforts are made to determine the ranges of these coefficients, which is referred to as sensitivity analysis [29].

Sensitivity analysis shows how well the alternatives perform for each objective and how sensitive they are to changes in the importance of the objectives. Determining the impact of changes in the values assigned by decision-makers during the relative evaluation of the methods used in the study is important for finding the optimal solution. Using the values in Table 9, the integrated risk scores of the analyzed work processes were obtained (Table 10). This approach enabled the systematic and objective evaluation of risk levels, ranked from highest to lowest, based on integrated scores.

Table 10. Integrated risk scores according to the weights determined by AHP

Process	Process steps	REBA	RULA	OWAS	MURİ	REBA (%)	RULA (%)	OWAS (%)	MURI (%)	Integrated score (%)
Sewing the face fabric	(1) Reach for the part	3	3	1	10	20	43	25	37	32
	(2) Sewing	5	4	2	11	34	57	50	41	45
	(3) Cutting	4	4	1	11	27	57	25	41	41
	(4) Reach for the machine	4	3	1	9	27	43	25	33	34
	(5) Drop the part	3	3	1	10	20	43	25	37	32
	(6) Change the thread and spool	2	4	1	9	13	57	25	33	35
Sponge laying	(7) Take the sponges	4	3	1	12	27	43	25	44	35
	(8) Take the bases	3	4	2	12	20	57	50	44	40
	(9) Reach for the glue gun (600gr)	2	3	1	10	13	43	25	37	29
	(10) Apply glue	3	3	1	10	20	43	25	37	32
	(11) Put down the glue gun	1	3	1	9	7	43	25	33	26
	(12) Stick the base to the sponge	3	3	2	11	20	43	50	41	34
	(13) Put the finished items aside	3	3	2	12	20	43	50	44	34
Priming or lining	(14) Take the sponge	4	3	1	11	27	43	25	41	35
	(15) Adjust the primer lining	2	3	1	12	13	43	25	44	30
	(16) Reach for the scissor	3	3	2	11	20	43	50	41	34
	(17) Cut the primer lining material	3	3	2	10	20	43	50	37	34
	(18) Reach for the stapler	3	3	2	9	20	43	50	33	33
	(19) Stapling	4	3	2	10	27	43	50	37	36
	(20) Reach for the knife	3	4	2	10	20	57	50	37	40
	(21) Open the mechanism	3	2	2	9	20	29	50	33	27
	(22) Put the finished items aside	3	3	2	10	20	43	50	37	34
Framework laying	(23) Take the frame	3	3	1	10	20	43	25	37	32
	(24) Take the cover	3	3	2	9	20	43	50	33	33
	(25) Put on the cover	3	3	1	10	20	43	25	37	32
	(26) Fix of the cover	5	3	1	11	34	43	25	41	38
	(27) Put the finished parts in the box	3	2	2	10	20	29	50	37	28
Wheel fitting	(28) Bring the materials to the table	3	2	1	10	20	29	25	37	26
	(29) Attach the wheel	4	2	1	9	27	29	25	33	28
	(30) Take the hub ring	3	3	2	12	20	43	50	44	34
	(31) Install the hub ring	4	2	2	9	27	29	50	33	30
	(32) Put the finished parts aside	5	4	1	9	34	57	25	33	43
Assembly process	(33) Take the bottom cover	1	4	1	9	7	57	25	33	32
	(34) Assemble the bottom cover	4	3	2	11	27	43	50	41	37
	(35) Take the mechanism	1	2	1	9	7	29	25	33	20
	(36) Assemble the mechanism	4	3	2	10	27	43	50	37	36
	(37) Leave the finished ones in the box	2	3	2	10	13	43	50	37	31
Packaging	(38) Take the legs	6	3	2	13	40	43	50	48	43
	(39) Put the legs in the box	4	3	2	11	27	43	50	41	37
	(40) Install the shock absorber	4	4	2	9	27	57	50	33	42
	(41) Close the box lids	6	3	2	10	40	43	50	37	42
	(42) Tape the box	7	5	2	13	47	72	50	48	58

The production processes of product A in the study consist of seven main stages: fabric stitching, frame upholstery, foam padding, lining, assembly, leg installation, and packaging. Each process also includes sub-processes, and a total of 42 processes were analyzed in the study. The physical strain experienced by workers during the production processes was analyzed using the REBA, RULA, OWAS, MURI, and AHP methods, and integrated risk scores were determined. The results are presented in Figure 2.

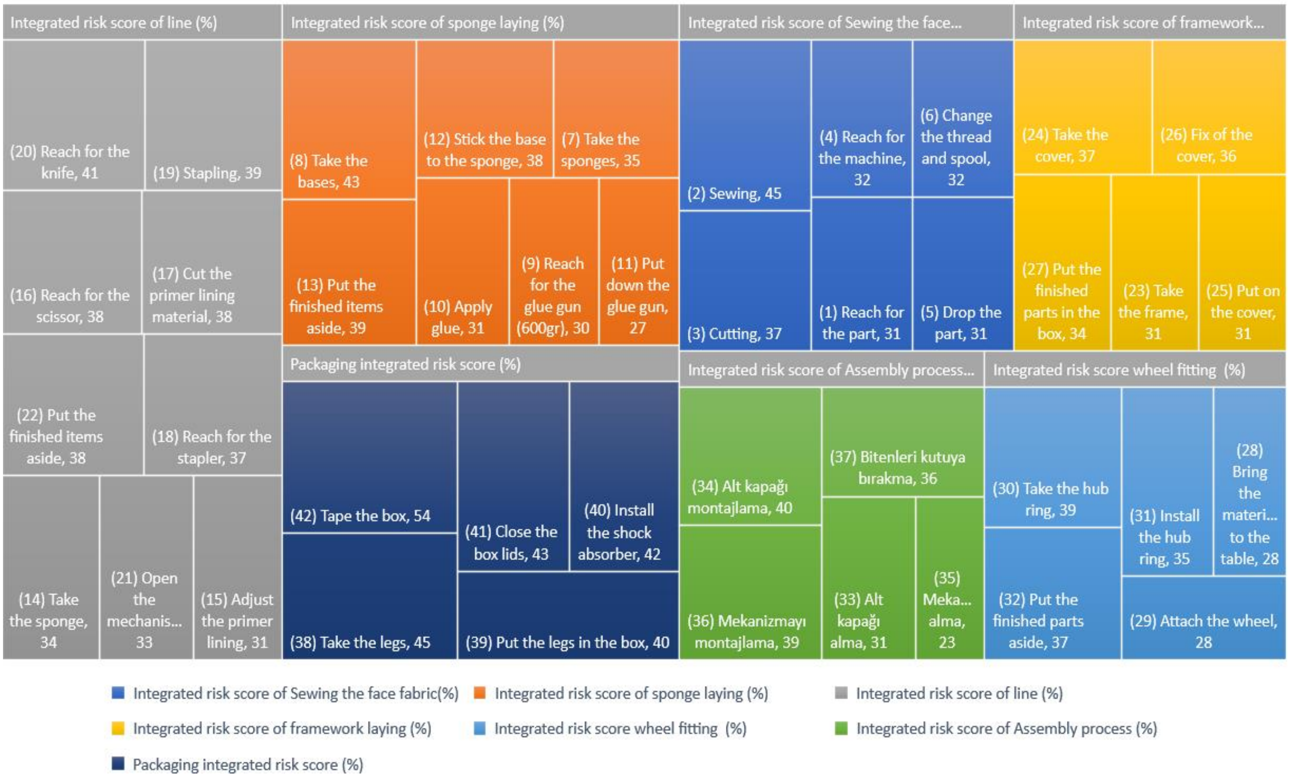

Figure 2. Integrated risk scores of processes

4. Conclusion and Recommendations

The data for the integrated ergonomic risk scores obtained using the AHP method are detailed in Table 10. From the data, the tasks with the highest risk levels were identified as box taping (58%), stitching (45%), placing finished parts aside (43%), retrieving legs (43%), closing box lids (42%), and Taking the Coasters (40%), in that order. Descriptions and recommendations related to the evaluated tasks are explained below.

BoxTaping: The worker performs the taping process of boxed materials by bending over on the ground with tape in hand. During this task, it is observed that the worker bends forward, while simultaneously twisting their torso and neck, extending their arms forward and outward, and maintaining an unbalanced position with their feet. These movements lead to associated risks.

Possible Measures:

- Adjustable workstations can be designed for placing boxes.
- Auxiliary tools (e.g., cutters, tape holders) can be utilized.
- Workers can be trained on proper working techniques (e.g., bending knees and keeping the back straight while working).
- Regular and sufficient breaks can be provided, along with regular stretching and tension-relief exercises.
- Task rotation can be implemented to avoid prolonged work in the same position.
- Frequently used items should be placed within easy reach

StitchingProcess: During this task, the worker operates a sewing machine while seated on a chair. During the process, workers are particularly exposed to risk factors related to back, neck, and wrist strain due to prolonged static posture.

Possible Measures:
- Chairs/seats with lumbar support and adjustable height can be used, along with footrests.
- Workers can be trained on proper working techniques (e.g., keeping the back straight while working).
- Fixtures that ensure easy access to auxiliary tools (e.g., needles, threads, etc.) can be utilized.
- Regular breaks can be provided to allow workers time to rest.
- Task rotation can be implemented to alternate workers between different duties.

Placing Finished Parts Aside: The worker lifts the assembled parts by hand and moves them to another location within the workshop to be packed. This process involves ergonomic risks such as back pain and excessive or repetitive strain on the knees and wrists due to lifting and carrying**.**

Possible Measures:
- Workers can be trained in proper lifting techniques, such as bending the knees and keeping the back straight.
- Finished parts can be carried with both hands to maintain body balance, and personal protective equipment, such as gloves, can be used.
- Workers can be provided with adequate and regular breaks.
- Tools like lift tables or scissor lifts can be used to elevate parts to waist height, reducing the need for bending.
- Surfaces where finished parts are placed should be designed to minimize bending at the waist.
- Safe weight limits should be established for lifting tasks, and mechanical assistance should be used for loads exceeding these limits.

Seat legs retrieval: The seat removes the legs from the apparatus where they were passed to fix them. While performing this operation, the amount of the feet is removed by bending down without bending the knees while the apparatus is small, and by lying down while the apparatus is excessive. During the procedure, the employee faces ergonomic risks such as bending forward on his back and bending forward at the waist when removing the legs, since the apparatus is far from the worker.

Possible Measures:
- Conveyor systems can be utilized to bring and transport the chair legs closer to the worker.
- Workers can be trained on proper lifting techniques, such as bending their knees and keeping their back straight while lifting and carrying objects.
- A job rotation system can be implemented to prevent workers from remaining in the same position for extended periods due to static posture.
- Stretching and flexibility exercises can be encouraged to allow muscles to recover and reduce the risk of injuries.
- Regular ergonomic assessments should be conducted to identify risk factors.

Closing Box Lids: In this task, the worker adds protective supports to the sides of the materials placed inside the box and then closes the lid. While performing this task, the worker is exposed to ergonomic risks such as leaning forward and sideways with their back, bending their neck, and rotating their arms forward and sideways due to the box height being insufficiently high, requiring them to work in a semi-bent posture.

Possible Measures:
- Boxes can be placed on pallets, carriers, or workbenches at waist height to minimize bending and reaching.
- Box lid closers or extendable tools that eliminate the need for bending can be utilized.
- Assistive tools should be positioned in easily accessible locations.
- Workers can be encouraged to bend by using their knees instead of their waist.
- Regular breaks and job rotation systems can be implemented.
- Comfortable and supportive footwear should be worn to reduce fatigue and maintain balance.

Taking the Coasters: In this task, the worker lifts plates weighing approximately 3-5 kg from boxes on the floor. During this process, the worker is exposed to ergonomic risks as they bend and rotate their back and lower back while lifting the materials.

Possible Measures:

- Workers can be trained on proper lifting techniques.
- Manual lifting equipment such as forklifts or lifting carts can be used to lift the bases.
- Adequate and regular breaks can be provided to workers, and/or job rotation can be implemented to prevent the repetition of the same movements.
- Safe weight limits for lifting should be established, and mechanical assistive devices should be used for loads exceeding these limits.
- Appropriate gloves can be provided to workers to reduce hand and finger strain.

This study analyzes processes in a labor-intensive furniture factory, considering 42 different work postures. As a result of analyses conducted using methods such as REBA, RULA, OWAS, and MUARI, risk scores for each job position were determined. Additionally, the weights of these scores were determined using the AHP method. The six job positions with the highest risk scores were identified, and detailed examinations were carried out for these positions, with improvement suggestions provided in detail.

The proposed solutions include measures that can be easily implemented and do not involve high costs, such as improving working conditions, making ergonomic adjustments, and ensuring the use of appropriate equipment. By implementing these measures, complaints related to musculoskeletal disorders and the risk of occupational diseases will be reduced, significantly increasing both work efficiency and employee satisfaction. The evaluations made in this study have objectively and systematically assessed the risk levels within the workplace and have played a guiding role in ergonomic improvements.

At every stage of production, employees perform tasks such as holding, lifting, carrying, packaging, and assembly. Repetitive execution of these seemingly simple tasks can lead to musculoskeletal disorders (MSDs) in areas such as the neck, back, arms, wrists, and knees. The main causes of these disorders are incorrect body posture, lack of planning, inappropriate task assignments without considering the workers' anthropometric characteristics, unsuitable workbench heights, and repetitive movements. Providing training to employees on handling and lifting processes, especially regarding ergonomics, will contribute to reducing MSDs. The results of this study demonstrate the critical importance of ergonomic adjustments in occupational health and safety. Such studies can make a significant contribution to the health and safety of employees in workplaces and can be applied to other similar businesses as well.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethics Committee Approval

Ethics committee approval is not required.

Author Contribution

All authors contributed to this study. All authors have read and agreed to the published version of manuscript.

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