SAKARYA ÜNİVERSİTESİ

FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 | e-ISSN 2147-835X | Period Bimonthly | Founded: 1997 | Publisher Sakarya University |
http://www.saujs.sakarya.edu.tr/

Title: Ergonomic Risk Assessment in the Forest Products Industry

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Recieved: 14.03.2023

Accepted: 2023-07-07 00:00:00

Article Type: Research Article

Volume: 27
Issue: 5
Month: October
Year: 2023
Pages: 1019-1035

How to cite
Merve YILMAZ, Muharrem ÜNVER; (2023), Ergonomic Risk Assessment in the Forest Products Industry. Sakarya University Journal of Science, 27(5), 1019-1035, DOI: 10.16984/saufenbilder.1265076
Access link
https://dergipark.org.tr/tr/journal/1115/issue/80257/1265076

Sakarya University Journal of Science 27(5), 1019-1035, 2023

Ergonomic Risk Assessment in the Forest Products Industry

Merve YILMAZ*[1], Muharrem ÜNVER[1]

Abstract

With the advancement of technology, the pressure on personnel in corporate operations has been reduced and productivity has increased. However, many industries continue to profit from labor. MSD can develop as a result of poor working conditions and repetitive movements. This research was carried out in a forest products enterprise with two facilities in Western Black Sea Region. The company produces construction timber using Fir and Pine as the base material. First, the demographic information of the field workers was obtained, then the musculoskeletal diseases of the local parts of the body were examined by using the Cornell (CMDQ) questionnaire. In the second step, REBA analysis was performed independently for the workstations determined in the company. According to the CMDQ study, employees reported the most strain on the lower back, back, and right wrist. It was determined that the most discomfort was in the lumbar region (35.90%). Again, according to the pain felt, it was seen that the most obstacles to work were caused by the waist, right upper leg and back. Scores overlap according to the common body regions evaluated in the Cornell and REBA analysis.

Keywords: Ergonomic risk assessment, cornell questionnaire, reba method, ergonomics, musculoskeletal system disorders

1. INTRODUCTION

Ergonomics science encompasses all efforts aimed at making people's living abilities more comfortable. Providing a work organization that aligns with the physiological characteristics of employees and improving ergonomic working conditions translates to increased productivity and profitability for employers. The goal of ergonomics is not solely to prevent occupational diseases and accidents. It also contributes to increased motivation and job performance through the improvement of working conditions. Ergonomics aims to optimize individuals' lifestyles for their own well-being [1].

As a result of continuous repetitive movements and ergonomically unfavorable body postures in the work environment, musculoskeletal disorders have become inevitable. Ergonomic risk factors that contribute to these disorders can be categorized into three main headings: work-related, personal, and environmental factors. Daily activities such as bending, squeezing, reaching, grasping, straightening, and even prolonged static positions can create

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ergonomic risks in the workplace. Factors contributing to the hazardous nature of these activities include high force requirements, rapid and repetitive movements, prolonged static postures, and insufficient time between movements.

Despite the development of technology reducing the physical workload of individuals in the workplace, musculoskeletal disorders maintain their significance among employee health problems. These physical risk factors in the work environment also have implications for employees' psychology. Situations such as lack of rest breaks or minimal breaks, temporal risk factors resulting from overtime, or reluctance towards work can be considered psychosocial risk factors. Personal risk factors include factors such as aging, smoking and alcohol consumption, weight, and medical history. Environmental risk factors can be created by conditions such as noise, slippery floor surfaces, and poor lighting in the workplace [2].

The forest products industry is a sector based on the processing and shaping of raw materials obtained from forests. The diversity of processing the natural form of wood before manufacturing the products can vary. This diversity can be divided into two main groups. The first group of activities involves the direct use of raw timber obtained from forests. This includes activities such as timber production, plywood manufacturing, packaging, veneering, plywood, paper industry, particleboard, and more. The second group of activities involves the use and processing of the products obtained from the first group as semi-finished goods. In this group, products such as parquet, carpentry, wooden prefabricated elements, toys, matches, musical instruments, etc., are produced.

Within the scope of this study, a timber production factory in the first group of activities is discussed. As in any industry, the installation and equipment used in the forest products industry contribute to improving production quality but also pose risks of accidents or occupational diseases [3] Equipment such as saws, milling and turning machines, raw material sizing machines, equipment used to reduce surface defects, rotating/moving parts, sharp and hazardous components or dust during the supply and processing of wood, can create hazardous work environments [4]. Additionally, improperly positioned conveyor belts can lead to risks such as excessive bending, twisting, or falling from heights for workers. Such situations can result in accidents, decreased worker performance, and long-term health issues.

Efforts are made to minimize factors that cause musculoskeletal disorders in employees through ergonomic risk assessment methods. These methods can be categorized into three classes: questionnaire, systematic, and direct measurement methods [5]. Questionnaire methods are cost-effective and easy to implement, but in production environments where ergonomic risks are considered high, it is recommended to use systematic or direct measurement methods. Ergonomic risk assessment methods can work individually or in combination based on the workplace activities, workplace requirements, number of employees, time required for work, and body parts exposed to ergonomic risks. In this study, a combination of observation-based methods such as REBA analysis and questionnaire methods such as CMDQ survey was used. Risk assessment targeting employees was conducted through the survey, and the production was analyzed ergonomically from both perspectives by conducting observation-based risk assessment using the REBA method.

The workplace conditions and working styles of employees in a timber production factory, which is one of the labor-intensive establishments, were thoroughly evaluated. The aim of this study was to determine the level of exposure to ergonomic risks such as posture, body mechanics, and repetitive movements for employees, and to identify measures to reduce these risks. Based on the applied methods within the scope of the study, it was observed that ergonomic adjustments should be made as soon as possible, and various recommendations were provided to the relevant departments of the company. It was observed that the holistic approach taken by using both systematic and questionnaire methods yielded more reliable results in the research scope.

The ongoing section of the study includes a literature review, a section describing the company and the production process, a methodology section detailing the methods used, an implementation section discussing the application of the study, and a findings and recommendations section.

2. LITERATURE REVIEW

Ünver and Kaya (2015) conducted a study evaluating the postures of 70 female workers employed in the reforestation operations at Trabzon-of Forest Nursery using the Rapid Entire Body Assessment (REBA) method to determine their risk levels. The REBA results indicated an ergonomic risk level of 7, signifying a moderate level of risk. It was suggested that measures should be taken regarding occupational health and safety and ergonomic arrangements in the workplace for workers identified to be at moderate risk[6].

Gönen et al. (2017) aimed to prevent workforce losses in a transformer manufacturing assembly line by using the Computerized Moving Diagram Quest (CMDQ), REBA, and Ovako Working Posture Analysis System (OWAS) methods. The study revealed that the most at-risk body parts were the back, waist, feet, and neck. To minimize these risks and enhance work efficiency under ergonomic conditions, an adjustable assembly table was recommended [7]. Nam et al. (2017) investigated the manual cleaning of residues such as gunpowder and mud from the barrel after firing heavy weapons like tanks and cannons in the armed forces. The REBA analysis indicated an urgent need for action, calling for preventive measures. The OWAS analysis also yielded similar results. It was recommended to use automated barrel cleaning tools to reduce these high ergonomic risks, resulting in REBA and OWAS scores being reduced to the second level. Nagaraj and Jeyepaul conducted a study in a textile industry establishment, assessing ergonomic risks related to poor posture among sewing machine operators. They employed the CMDQ questionnaire and REBA analysis. The study found a mismatch between the operators' body dimensions and the machine. Furthermore, prolonged standing resulted in discomfort in the lower back region. Recommendations included adjusting the height of workstations within the company, incorporating breaks and exercises to ensure continuity[8]. Yalçın and Ayvaz (2018) conducted an ergonomic risk assessment for workers operating on four different workstations in a wheel production factory. The study identified the workstations with the highest strain based on the production process and determined the physical strains using the REBA and Quick Exposure Check (QUEC) methods. Recommendations were provided to reduce risks for two workstations with high REBA and QUEC scores. The implemented improvements aimed to minimize risks[9].

Gündüz and İde (2021) examined musculoskeletal system disorders and fatigue levels among students engaging in online education during the pandemic. The Checklist Individual Strength (CIS) and CMDQ questionnaire were used to analyze fatigue levels. Results showed that 84.1% of the students felt fatigued. According to the Cornell scale, the most commonly reported discomfort was in the lower back (18.25%), followed by the neck and shoulder regions. A positive and significant correlation was found between students' fatigue and Cornell discomfort scores. When the Cornell questionnaire was divided into two parts (night-day) for participants, it was observed that shoulder risk scores significantly differed between night-shift and day-shift students[10].

Aydın (2021) conducted an ergonomic risk analysis for employees working in a retail store selling meat and poultry products. The NIOSH equation was used for manual lifting operations, and the REBA method was employed to assess working postures in the store. It was identified that manual lifting during order preparation posed a high risk level, and the recommendation included the use of adjustable pallet jacks. Furthermore, it was emphasized that the loads carried by employees should be reduced through improvements. After implementing the proposed methods, the REBA risk score decreased from 9 to 3[11]. Geniş and Sümer (2021) analyzed the body postures of seasonal workers engaged in seed corn farming, which can lead to musculoskeletal disorders, using the REBA method. They conducted separate evaluations for each work model and provided recommendations for each work model[12].

Kızgın et al. (2022) investigated the body parts where musculoskeletal disorders are most prevalent among hairdressers and examined the relationship between upper extremity problems and occupational burnout. The study included 78 hairdressers. Musculoskeletal disorders were determined using the Cornell questionnaire, and the level of burnout was assessed using the TÖ-KF form. The study found that the participants experienced the most discomfort in the neck and lower back regions. Additionally, a high and positive correlation was found between upper extremity disorders and occupational burnout.

Protective rehabilitation programs were recommended for hairdressers[13]. Altunel (2022) conducted an ergonomic risk assessment for employees working in both the offices and chemical storage facilities of a company in the chemical sector. The ROSA and CMDQ questionnaires were used for office workers, and the REBA method was used for chemical storage facility workers. The study involved both observer and participant observations for office workers. The study found that the chairs of office workers were not sufficiently ergonomic, and the workers in the storage facility experienced postural problems due to load lifting activities. Recommendations were provided for addressing non-ergonomic working conditions. Yurdalan et al. (2022) investigated the effects of postures and respiratory exercises on quality of life and potential pain for home and office workers. The study included 61 volunteer workers aged between 20 and 50. According to the CMDQ questionnaire, significant differences were observed in the scores for the lower back, neck, and left forearm among the groups. No significant differences were found in terms of quality of life based on the SF-36 questionnaire. It was observed that exercise-focused physiotherapy approaches resulted in a reduction in musculoskeletal disorders and an improvement in quality of life for the workers[14].

Considering that this study is being conducted in the forest products industry, which is one of the labor-intensive industries, it highlights the importance of ergonomic risk assessment studies for lumber production as well. Like any labor-intensive manufacturing operations, lumber production involves movements that can cause musculoskeletal disorders. The Cornell questionnaire is a self-reporting method. In addition to such ergonomic risk assessment questionnaires, it would be appropriate to analyze the causes and consequences of the problem from a broader perspective by using observation-based methods.

3. MATERIAL AND METHOD

The study was conducted for the employees working on the production line of a factory operating in the forest products sector. The factory is comprised of two facilities and has a total of 55 employees, serving both domestic and international markets. Since its establishment, the factory has been engaged in the production of furniture and construction timber using poplar, fir, and pine as raw materials.

The factory operates from 08:00 to 18:00 with three breaks during the day, including a lunch break. The process flow of timber production is presented in Figure 1. The production of timber begins with the arrival of logs to the log yard and their dimensioning according to customer orders. After cutting, the logs are sent to the resaw machines, where the bark is removed using band saws. The straight-shaped pieces, excluding the bark, are then subjected to multiple ripping, edging, and trimming operations.

Multiple circular saws enable the removal of sides from the timber or the simultaneous production of multiple materials with equal thickness. Next, the timber is sent to the trimming machine for full-length sizing based on the orders. The quarter sawing machine (Markul) cuts the thick caps from the main machine and trims the sides of the parallel-cut timber. Subsequently, the edging/trimming process takes place. The edging machine is used to remove the sides of the parallel-cut timber or to obtain standard construction timber from the similarly processed timber.

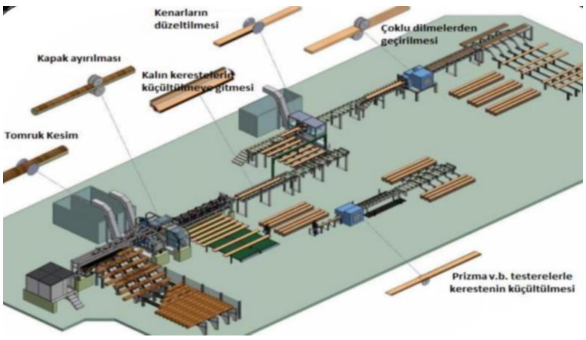


Figure 1. Timber Production Process

In order to directly impact employee health and motivation, non-ergonomic work conditions will also have consequences on work efficiency. In this context, businesses should assess the risk factors that contribute to musculoskeletal disorders (MSDs) and take necessary precautions. There are several scientific methods available for evaluating ergonomic risk factors. These methods can be broadly classified into three categories, as outlined in Table 1: self-reporting by employees, systematic observation-based methods, and direct measurement methods. Examples of self-reporting methods include the Nordic Musculoskeletal Questionnaire (NMQ), Cornell Musculoskeletal Disorder Questionnaire (CMDQ), and Body Discomfort Diagram (BPDS). Advanced observation-based methods include Rapid Upper Limb Assessment (RULA), Occupational Repetitive Actions (OCRA), Quick Exposure Check (QUE), Working Posture Analysis (OWAS), Builder Model, SANTOS, PoenSim, 3DSSPP, and Ramsis Model. Quantitative assessments using devices such as goniometers, biomechanical analysis, electromyography, and optical tools fall under the category of direct measurement methods. In this study, the REBA method, a simple observation-based method, and the CMDQ questionnaire, a method based on self-reporting by employees, were applied[15].

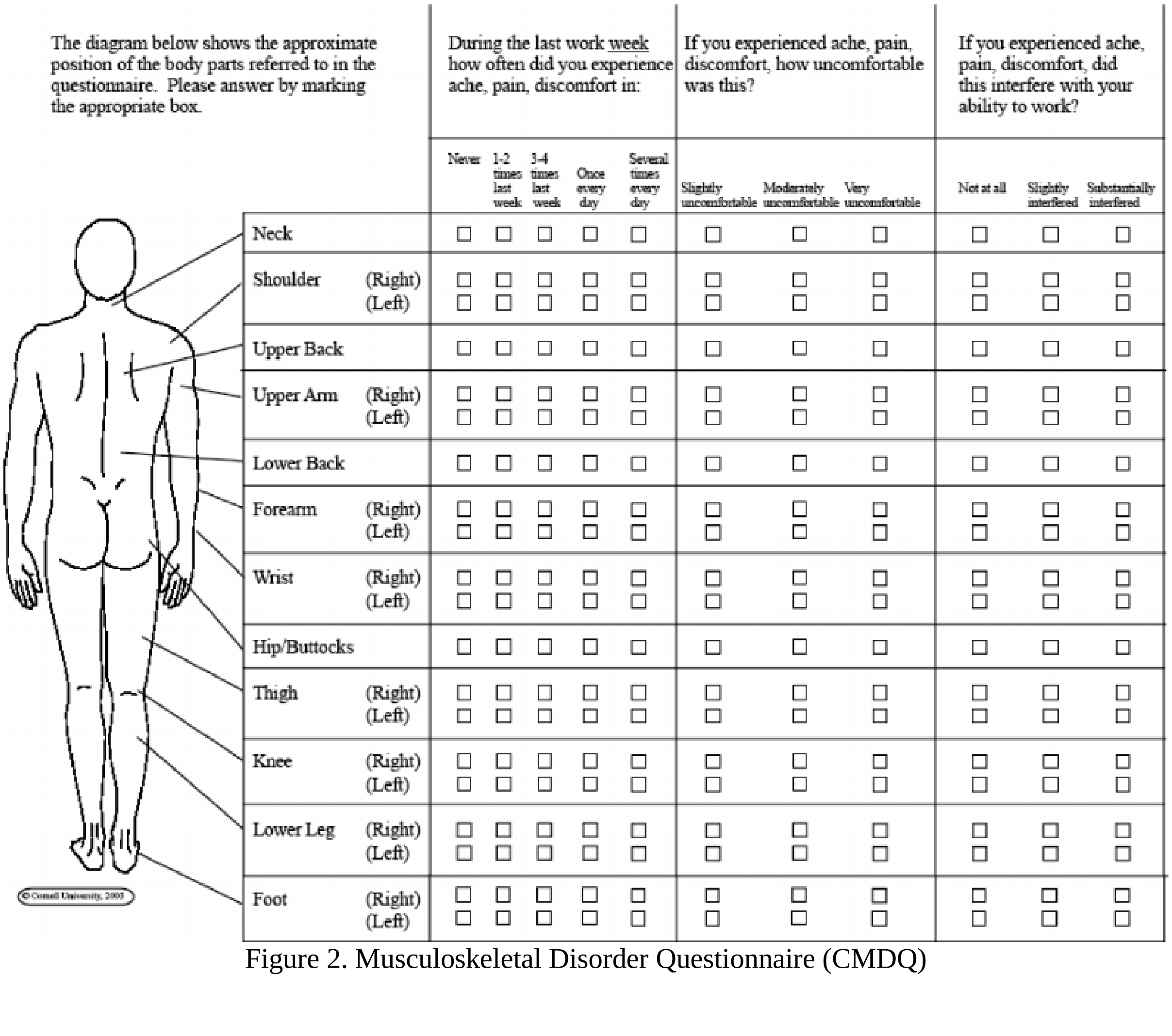
3.1. Cornell Musculoskeletal Disorder Questionnaire (CMDQ)

The Cornell Musculoskeletal Disorder Questionnaire (CMDQ) is a method developed by Dr. Alan Hedge and graduate students in the field of ergonomics at Cornell University's Human Factors and Ergonomics Laboratory. It is a valuable tool for gathering data on musculoskeletal disorders, providing a separate evaluation for each region of the body. The CMDQ questionnaire considers the frequency, severity, and interference of musculoskeletal discomfort in each body region, including their impact on work. This assessment helps evaluate the consequences of discomfort on employees' job performance[7]. The questionnaire has separate forms for individuals working in a standing position and those working in a seated position. In this study, the CMDQ questionnaire form designed for male individuals working in a standing position, as shown in Figure 2, was used[16].

According to the form, the risk score calculation is based on frequency scores: never felt it = 0 points, felt it 1-2 times per week = 1.5 points, felt it 3-4 times per week = 3.5 points, felt it once a day = 5 points, and felt it multiple times a day = 10 points. Pain severity is scored as follows: mild = 1 point, moderate = 2 points, severe = 3 points. The interference of discomfort with work activities is assessed as follows: no interference = 1 point, slight interference = 2 points, significant interference = 3 points.

3.2.REBA Method

REBA method was first proposed in 1998 by Hignett and McAtamney. It is a method designed for the analysis of strenuous, frequently repetitive, and unpredictable body postures. [17] The method involves assigning scores to each region of the body involved in performing a task to quantify the risks. This method is based on observation, where the evaluator assesses posture positions by reviewing photographs and videos[18]. In REBA analysis, both the right and left sides of the body are evaluated together. The body parts are generally divided into Group A and Group B, as shown in Table 1. Group A includes the assessment of the trunk, neck, and legs, while Group B includes the assessment of the upper arm, forearm, and wrists. Different angle values are assigned for each relevant body part. The total score is obtained by combining the scores from Group A and Group B.



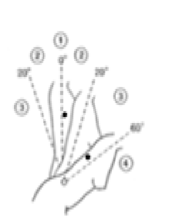
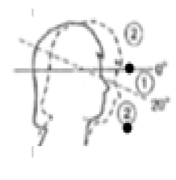
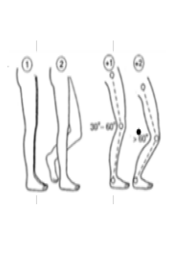
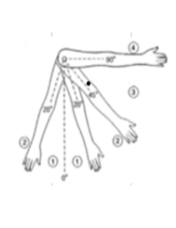
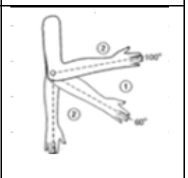
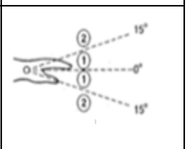
The diagram below shows the approximate position of the body parts referred to in the questionnaire. Please answer by marking the appropriate box.

Body part	Side	During the last work week how often did you experience ache, pain, discomfort in:					If you experienced ache, pain, discomfort, how uncomfortable was this?			If you experienced ache, pain, discomfort, did this interfere with your ability to work?		
		Never	1-2 times last week	3-4 times last week	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Foot	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

©Cornell University, 2003

Figure 2. Musculoskeletal Disorder Questionnaire (CMDQ)

Table 1 REBA Score

	Movement	Point	Change Point	Position
Body	Posture	1	Lateral stretch or a twisting movement, add +1 point.	
	0°-20° flexion	2		
	0°-20° stretching			
	20°-60° stretching	3		
	>20º stretching			
	>60º flexion	4		
Neck	0°-20° flexion	1	Lateral stretch or a twisting movement, add +1 point.	
	>20° flexion	2		
Legs	If the weight is distributed on both legs while walking or sitting.	1	The knees are bent between 30 degrees and 60 degrees, add +1 point; or the knees are bent >60 degrees, add +2 points.	
	If the weight is on one leg or if there is an unbalanced posture	2		
Upper Arm	0°-20° flexion	1	Extension and rotation movement in the arm add +1; ıf the shoulders are raised, add +1; ıf the arms -1	
	0°-20° stretching			
	20°-45° flexion	2		
	>20° streching			
	45°-90° flexion	3		
	>90° flexion	4		
Forearm	60°-100° flexion	1		
	<60° flexion	2		
	>100° flexion			
Wrist	0°-15° flexion		Lateral stretching or rotation in the wrist	
	15 streching			
	>15° flexion			
	>15° stretching			

When analyzing the photographs and videos of employees' postures, separate scores for the neck, trunk, and legs are determined based on the categories provided in Table 1. These scores are then cross-referenced in Table 2. The load imposed on the employee during the task is assessed based on the load force score in Table 2 and added to obtain the total A score.

Table 2 REBA A Score

Table A		*Neck*											
		1				2				3			
Legs		1	2	3	4	1	2	3	4	1	2	3	4
Torso	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Charge/Force Points			
0	1	2	+1
less than 5 kg	5-10 kg	>more than 10	Add +1 when power usage suddenly or rapidly increases

In Table 3, the stance scores for the wrist, lower arm, and upper arm in the B cells are crossed over. The total score in Table B is created by adding the second score from Table 3 to the combination score. Scores from Tables A and B are compared to Table C. The REBA score is calculated by adding the activity score from Table 4 to the C score.

In Table A, a cross-referencing is conducted between the scores obtained from the trunk, neck, and leg assessments, and in Table B, the scores obtained for the upper arm, forearm, and wrist assessments. This cross-referencing process is performed in Table C. The appropriate activity score specified in the table is added to the cross-referenced C score. The resulting C score becomes the REBA score.

Table 3 REBA B Score

Table B		*Lower Arm*					
		1			2		
Wrist		1	2	3	1	2	3
Upper Arm	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Suitable and reasonable holding forces of the necessary apparatus	0
Adequate but unsatisfactory hand grip supported anywhere on the body	1
No holding hands, but it's possible (weak)	2
Cannot support or hold anything	3

Table 4 REBA C Score

Table C		B Score											
		1	2	3	4	5	6	7	8	9	10	11	12
A Score	1	1	1	1	2	3	3	4	5	6	7	7	7
	2	2	2	2	3	4	4	5	6	6	7	7	8
	3	3	3	3	3	4	5	6	7	7	8	8	8
	4	4	4	4	4	5	6	7	8	8	9	9	9
	5	5	4	4	5	6	7	8	8	9	9	9	9
	6	6	6	6	7	8	8	9	9	10	10	10	10
	7	7	7	7	8	9	9	9	10	10	11	11	11
	8	8	8	8	9	10	10	10	10	10	11	11	11
	9	9	9	9	10	10	10	11	11	11	12	12	12
	10	10	10	10	11	11	11	11	12	12	12	12	12
	11	11	11	11	12	12	12	12	12	12	12	12	12
	12	12	12	12	13	12	12	12	12	12	12	12	12

Score	*Definition*
+1	One or more body parts are static
+1	If there are repeated short-term actions
+1	If the action causes rapid drastic changes in posture or there is unstable posture

The risk levels and action levels associated with the calculated REBA risk score are determined according to Table 5. A score of 8-10 points on the REBA scale indicates a high risk level and the need for improvement in the near future. If the score falls within the range of 11-15 points, the risk level is very high, and immediate action should be taken.

Table 5 REBA Risk Scores

Level	*REBA Score*	*Risk Level*	*Precaution*
1	1	Negligible	Not Necessary
2	2-3	Low	May be necessary
3	4-7	Middle	Necessary
4	8-10	High	Necessary in a Short Time
5	11-15	Very High	Needed Immediately

4. APPLICATION

In this study, the physical exertions of individuals during lumber production, such as lifting, dropping, and carrying heavy materials, were evaluated ergonomically. The study consisted of two parts, starting with the selection of 40 male volunteers for the CMDQ questionnaire, which focused on Cornell musculoskeletal disorders. The first part of the questionnaire collected demographic information of the workers (age, weight, height, education level, industry experience) and work-related details (working style, weight lifted, department worked in). This information is presented in Table 6.

The average age of the 40 participants in the survey is 34.03, with an average height of 173.73 cm and an average weight of 74.03 kg. The average duration of experience in the company is more than 4.5 years. Among the participants, 52% have completed primary school education. The production line is divided into six separate units. The majority of the workers (25%) are involved in the cutting unit, including multiple and secondary-stage cutting, as well as the stacking unit. In terms of work style, 65% of the employees work standing, 25% work walking, and 10% work sitting. Those who work walking are mainly in the sorting unit, while those who work sitting are usually operators. The musculoskeletal disorders of the workers are directly related to the materials they handle and their work style. As the average weight of the produced lumber is 25 kg or more, it is observed that 50% of the workers carry weights exceeding 20 kilograms. Individuals operating the cutting machine, collecting and stacking small slats or logs, or working as operators are considered to handle materials weighing less than 10 kg.

Table 6 Information for employees

Demographic Information	N	Average	Std. Deflection
Age	40	34.03	10.307
Height	40	173.73	5.782
Weight	40	74.03	13.26
Experienced	40	4.73	4.58
Worked Production Unit	Frequency	Percentage (%)	Cumulative Percentage
Log Cutting	4	0.10	0.10
Longitudinal saw	6	0.15	0.25
Stacking	10	0.25	0.50
Side cut	5	0.13	0.63
Mower	10	0.25	0.88
General	5	0.13	1.00
Total	40	1.00	
How Does an Individual Work?	Frequency	Percentage (%)	Cumulative Percentage
afoot	26	0.65	0.65
On foot	10	0.25	0.90
Sitting down	4	0.10	1.00
Total	40	1.00	
Lifted Weight	Frequency	Percentage (%)	Cumulative Percentage
<10 kg	13	0.33	0.33
10-20 kg	7	0.18	0.50
>20 kg	20	0.50	1.00
Total	40	1.00	

4.1. Cornell Musculoskeletal Disorder Questionnaire (CMDQ) Application

The frequency, severity, and work interference scores obtained from the responses to the Cornell Musculoskeletal System questionnaire by the employees are provided in Table 7.

According to the CMDQ questionnaire, for example, the risk score calculation for the back region is as follows: frequency score (140) + (131.5) + (73.5) + (45) + (210) = 84, weighted severity score (51) + (192) + (23) = 49, and work interference discomfort score (111) + (132) + (2*3) = 43, resulting in a total discomfort score of 176988 when multiplied together. According to the Cornell questionnaire results, the highest risk scores are attributed to the lower back (31.78%), followed by the back (11.34%), right wrist (10.31%), and right forearm (9.15%). It is observed that the employees experience the highest level of pain in the lower back region (35.90%). Furthermore, work interference is predominantly associated with discomfort in the lower back, upper right leg, and back.

4.2.REBA Method Aplication

REBA analysis was conducted separately for each unit of the timber production line. Photographs and videos were taken from different angles to assess the employees' postures. Each posture was then examined in detail, and the REBA score was calculated for the posture with the highest level of risk.
The REBA analysis for the stacking unit is presented in Figure 3. Since the load in the employee's hand is heavier than 20 kilograms, a force score of 2 is assigned. The trunk posture is mostly at or above 60 degrees (4 points), with lateral bending and twisting (+1 point) due to picking up the materials from the side. For the neck region, there is a maximum of 20 degrees of flexion (1 point) and stretching (+1 point). Additionally, the weight is distributed on both legs (1 point), and the knees are flexed to a maximum of 60 degrees (+1 point). In the upper arm, there is a maximum of 20 degrees of flexion (+1 point), and abduction or rotation movement is present (+1 point). The forearm exhibits flexion above 60 degrees (2 points), while the wrists have a maximum of 15 degrees of extension. Thus, a Table A score of 7 is obtained for employees in the stacking unit.

Table 7 CMDQ Survey Results

CMDQ SURVEY		**How often have you felt aches, pains, discomfort in your body during the past working week?**					**If you felt aches, pains, discomfort, how severe was it?**			**Percentage %**	**Have you experienced pain, ache, or discomfort that prevented you from performing your tasks?**			**Percentage %**	**Average Risk Score**	**Score Percentage (%)**
Body Part		**None**	**1-2 times a week**	**3-4 times a week**	**1 time per day**	**Many Times Eevery Day**	**Llittle**	**Middle**	**Lot**		**Little**	**Middle**	**Lot**			
Neck		22	13	4	1	0	7	11	0	0.00	14	4	0	0.00	24563	1.57
Shoulder	Right	24	9	4	3	0	9	6	1	2.56	12	4	0	0.00	20400	1.31
	Left	26	13	1	0	0	9	4	1	2.56	11	3	0	0.00	7820	0.50
Back		14	13	7	4	2	5	19	2	5.13	11	13	2	9.52	176988	11.34
Upper Arm	Right	20	9	7	2	2	5	13	2	5.13	9	10	1	4.76	80512	5.16
	Left	22	11	7	0	0	4	13	1	2.56	9	9	0	0.00	36531	2.34
Waist		11	7	5	11	6	4	11	14	35.90	14	8	7	33.33	495924	31.78
Forearm	Right	14	10	11	4	1	10	13	3	7.69	15	10	1	4.76	142785	9.15
	Left	16	10	11	3	0	9	12	3	7.69	14	9	1	4.76	100695	6.45
Wrist	Right	11	15	10	3	1	11	15	3	7.69	20	8	1	4.76	160875	10.31
	Left	13	13	10	3	1	11	13	3	7.69	19	7	1	4.76	131652	8.44
Hip		32	1	2	0	5	0	8	0	0.00	8	0	0	0.00	7488	0.48
Upper leg	Right	18	10	9	2	1	13	8	1	2.56	15	3	4	19.05	70224	4.50
	Left	20	10	8	2	0	12	7	1	2.56	15	2	3	14.29	43036	2.76
Knee	Right	31	7	1	0	1	8	1	0	0.00	8	1	0	0.00	2400	0.15
	Left	29	8	2	0	1	9	2	0	0.00	10	1	0	0.00	4524	0.29
Lower Leg	Right	26	7	5	2	0	6	8	0	0.00	13	1	0	0.00	12540	0.80
	Left	24	9	5	2	0	6	10	0	0.00	13	3	0	0.00	20254	1.30
Foot	Right	28	3	5	4	0	8	2	2	5.13	10	2	0	0.00	10584	0.68
	Left	28	3	5	4	0	8	2	2	5.13	10	2	0	0.00	10584	0.68

REBA Analysis For Stacking Unit					
Group A		Score A	Score B	Score B	
Torso	5	7	2	Lower Arm	2
Neck	2			Upper Arm	2
Legs	2			Wrist	1
Strength Points		2	0	Grip Score	
Score A		9	2	**B Score**	

C Score	**9**
Activity Score	**1**
REBA Score	**10**

Figure 3 Stacking Unit REBA Evaluation

The high Table A score is due to the intensive use of the trunk and arms in the process of lifting, carrying, and stacking materials. After obtaining the A and B scores, cross-referencing is done from Table C. Then, based on the nature of the task, a score is added. For this example, since there is no prolonged static posture, no significant rapid changes in posture, and repeated movements within a short period (such as stacking logs at least 3 times per minute), a +1 score is added from Table C, resulting in a total REBA Score of 10. This score indicates a high ergonomic risk level in the relevant unit and the need for prompt action to address the employee's musculoskeletal disorders.

Scores For Longitudinal Unit REBA					
Group A		Score A	Score B	Score B	
Torso	4	6	5	Lower Arm	4
Neck	2			Upper Arm	2
Legs	2			Wrist	1
Strength Points		2	0	Grip Score	
Score A		8	5	**B Score**	

C Score	**10**
Activity Score	**1**
REBA Score	**11**

Figure 4 Scores for Longitudinal Unit REBA

The REBA analysis for the sizing unit is presented in Figure 4. The employee exhibits a trunk stretching posture of 20 degrees or more (3 points) and also lateral bending or twisting (+1 point). There is a maximum of 20 degrees of flexion in the neck (1 point) and rotational movement to the right and left (+1 point). While walking, the weight is distributed on both legs (1 point), and the knees are flexed between 30 and 60 degrees (+1 point). In the upper arm, there is flexion above 45 degrees (3 points) and abduction movement (+1 point). The lower arm exhibits slight flexion (2 points), and there is slight extension in the wrists (1 point). Since the weight lifted exceeds 20 kilograms, a force score of 2 is assigned, resulting in a total Table A score of 8. The Table B score is 5. Cross-referencing in Table C yields a score of 10, resulting in a total REBA Score of 11. This score indicates a high ergonomic risk level in the relevant unit and the need for immediate action to address it.

Multi-Slitting REBA Scoring					
Group A		Score A	Score B	Score B	
Torso	3	5	2	Lower Arm	2
Neck	2			Upper Arm	2
Legs	2			Wrist	1
Strength Points		2	0	Grip Score	
Score A		7	2	**B Score**	

C Score	**7**
Activity Score	**1**
REBA Score	**8**

Figure 5 Multi-Slitting REBA Scoring

The multiple cutting REBA analysis is presented in Figure 5. By combining the total A and total B scores for the employee who supplies the material to the machine, a total C score of 8 is obtained. This score indicates a high-risk level within the low range, emphasizing the need for immediate action to address the ergonomic concerns.

Trimming Unit REBA Score					
Group A		Score A	Score B	Score B	
Torso	3	5	2	Lower Arm	2
Neck	2			Upper Arm	2
Legs	2			Wrist	1
Strength Points		2	0	Grip Score	
Score A		7	2	B Score	

C Score	7
Activity Score	1
REBA Score	8

Figure 6 Timber Chopper REBA Evaluation

The REBA analysis conducted for the trimming unit resulted in a Table A score of 7 and a Table B score of 2, as shown in Figure 6. The total REBA score is determined as 8, indicating a high action level and the need for prompt intervention within this unit.

Trimming Unit REBA Score					
Group A		Score A	Score B	Score B	
Torso	3	5	2	Lower Arm	4
Neck	2			Upper Arm	2
Legs	2			Wrist	1
Strength Points		2	0	Grip Score	
Score A		7	6	B Score	

C Score	9
Activity Score	1
REBA Score	10

Figure 7 Markule Unit REBA Scoring

For the operator of the marking machine, the total REBA score is determined as 10, as shown in Figure 7. In this case, the action level is high-risk, indicating the need for prompt intervention within a short period of time.

5. RESULTS AND DISCUSSION

In the study, the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) was used to evaluate the 40 voluntary participants based on their questionnaire responses. The results were analyzed, and the highest risk scores were found to belong to the lower back (31.78%), the upper back (11.34%), the right wrist (10.31%), and the right forearm (9.15%). It was observed that the employees experienced the highest level of pain in the lower back region (35.90%). Furthermore, the highest rate of work interference due to pain was reported in the lower back, right upper leg, and upper back.

The graphical representation of the results obtained from the Cornell Musculoskeletal Discomfort Questionnaire for the employees is presented in Figure 8.

According to the information obtained from the Cornell results, it is observed that the majority of musculoskeletal disorders occur in the lower back region (31.78%). Within the field, except for operators, machine operators, and employees performing light tasks, most employees are required to stand and engage in frequent bending and stooping movements. Activities such as placing materials into the machine, retrieving leftover materials from the machine for evaluation, and transporting them to the storage area pose a risk of musculoskeletal disorders for the employees.

It has been observed that employees generally complain of lower back pain (bel ağrısı) due to the lifting and carrying of heavy materials. To mitigate work interference caused by these ergonomic discomforts and ensure employee health and safety, several breaks are provided throughout the day.

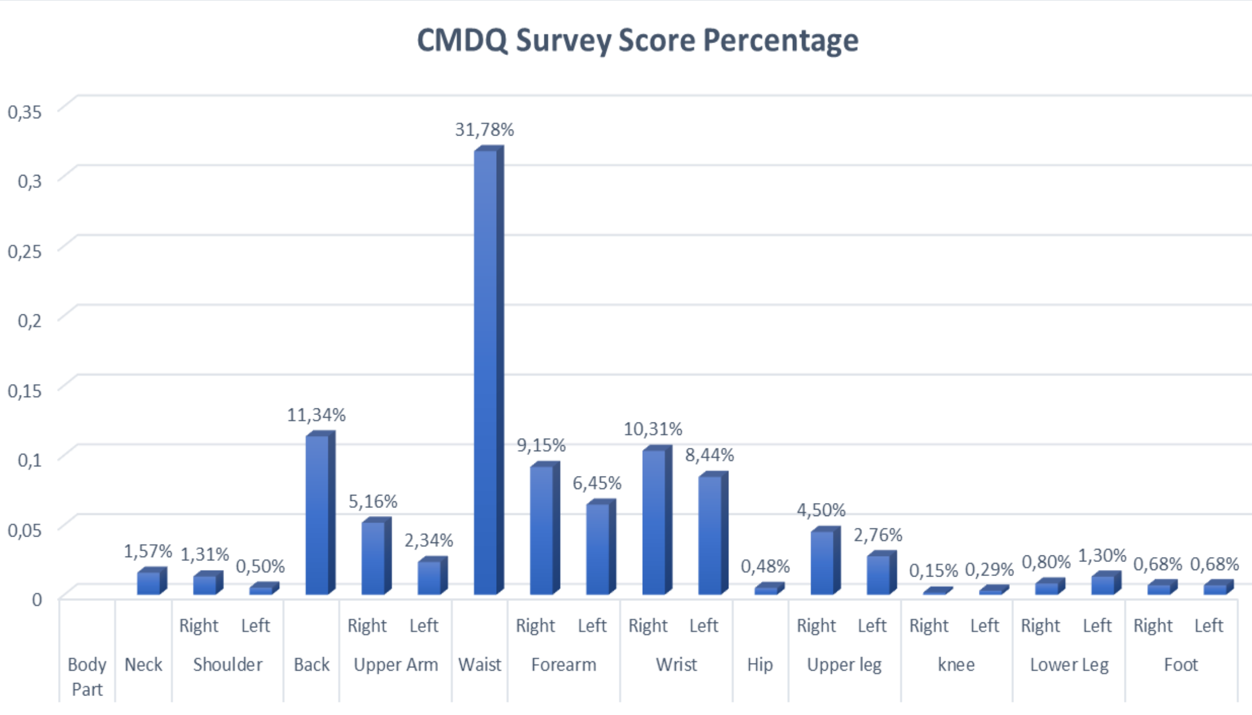


Figure 8 Percentage of CMDQ Survey Risk Scores

After the lower back region, the highest risk scores are observed in the right wrist (sağ el bileği) (10.31%) and the upper back (sırt) (11.34%). The similarity in results between the lower back and upper back regions is due to the use of significant physical effort in handling the large prismatic materials obtained from the multiple cutting machine. Transporting these materials via a conveyor can reduce the workload for workers. Unconscious lifting of heavy loads can also contribute to back and lower back pain. Therefore, it is necessary to provide appropriate training within the company. The least ergonomic risk is associated with the right knee region (sağ diz) (0.15%). Since employees predominantly use their right hand, it is expected that there will be physical strain on their right wrists. The low score for the knee region can be attributed to the absence of physical activities involving squatting. According to Table 8, which shows the calculated REBA action levels for the work units, the trimming unit has the highest risk level. In this unit, the products obtained from multiple cutting are transported to the trimming machine for sizing. The handling of these heavy and bulky materials predominantly involves the use of the trunk and arms. Immediate measures should be taken to minimize the exposure of employees in this unit to musculoskeletal disorders.

Activities such as placing materials into the machine, retrieving leftover materials from the machine for evaluation, and transporting them to the storage area pose a risk of musculoskeletal disorders for the employees. It has been observed that employees generally complain of lower back and upper back pain due to the handling and transportation of heavy timber materials. Similar to the study conducted by Ünver et al. (2021), automation systems can be implemented in the production process to reduce the workload on employees for repetitive and continuous movements. In the mentioned study, conducted in the chemical industry, autonomous systems were designed for employees handling hazardous substances [19]. Similarly, timber production, like the chemical industry, involves various hazardous machinery in the production process, posing threats to employee safety.

Table 8 REBA Scores

	A Score			B Score			REBA Score	
Unit / Body Part	Torso	Neck	Leg	Upper Arm	Lower arm	Wrist	Risk Score	Risk Level
Longitudinal saw	4	2	2	4	2	1	11	Immediate action must be taken
Stacking	5	2	2	2	2	1	10	Action should be taken as soon as possible
Multiplicity Slitting	3	2	2	2	2	1	8	Action should be taken as soon as possible
Side cut	3	2	2	2	2	1	8	Action should be taken as soon as possible
Markule	3	2	2	4	2	2	10	Action should be taken as soon as possible

6. CONCLUSION

With the advancement of technology in modern times, although machines help alleviate the burden on humans in the production processes, complete automation is not always achievable, and the human factor cannot be eliminated. In places where the human factor is present, issues such as occupational health and safety cannot be ignored. Particularly in labor-intensive industries, being aware of the science of ergonomics is crucial for both employees and employers. The exposure of employees to non-ergonomic working conditions directly affects production quality, resulting in reduced profitability and work performance for businesses. Like many other sectors, the forest products industry involves certain ergonomic risks in the primary and secondary processing stages of raw materials. Furthermore, repetitive movements, lifting and carrying heavy materials, and other activities in labor-intensive operations lead to musculoskeletal disorders in employees.

This study was conducted in an enterprise operating in the forest products industry in the Western Black Sea Region. In the first part of the study, musculoskeletal disorders observed in individuals due to working conditions were evaluated by assessing specific body areas using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). Activities such as placing materials into the machine, retrieving leftover materials from the machine for evaluation, and transporting them to the storage area pose a risk of musculoskeletal disorders for the employees. It has been observed that employees generally complain of lower back and upper back pain due to the handling and transportation of heavy timber materials. According to the REBA analysis, the highest occurrence of musculoskeletal disorders was found in the trimming unit. The visual assessment of the employee during the highest ergonomic risk situation in this unit resulted in a risk score of 11. The employee is required to continuously lift and carry materials weighing more than 20 kg while arranging the parts from the multiple cutting machine in front of the trimming machine, which contributes to a high risk score in the trunk category. Due to the intense use of the back, upper back, and arms, the load imposed on the employee's body leads to musculoskeletal disorders and the need for frequent breaks. Transporting the heavy and bulky materials from the multiple cutting machine to the trimming stock area via conveyors or using forklifts would alleviate the employee's load.

The body areas evaluated in the Cornell questionnaire, such as the lower back and upper back, correspond to the trunk assessment in the REBA method. The questionnaire evaluation and the observation-based analysis in the REBA method reveal non-ergonomic postures for the same body regions. The company provides two breaks of 15 minutes each, at 10:30 AM and 2:30 PM. It was determined that employees become more fatigued within the field and require intermittent rest. Increasing the rest periods for individuals in continuous working conditions would help alleviate body fatigue and enable safe continuation of work. The manner of lifting materials is also crucial. Incorrect grasping and lifting of heavy materials from the floor increase the load on the back and neck.

Practical workplace training sessions on proper material handling techniques should be conducted multiple times a month to raise awareness among employees. Additionally, it was observed that individuals use technological devices such as phones or headphones during production. In occupational health and safety training provided by professionals, it is appropriate to address or prohibit the use of such devices for the sake of safety.

Funding
The author (s) has no received any financial support for the research, authorship or publication of this study.

Authors' Contribution
In this study, Author 1 was responsible for the literature review, use of questionnaires, data collection, statistical analysis, writing of the article, and interpretation; Author 2 was involved in idea generation, method selection, model construction, analysis, interpretation, and final control of the findings and results.

The Declaration of Conflict of Interest/ Common Interest
No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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