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Assessing Ergonomic Risks in Worker Postures: The Case of Belt Conveyor Assembly

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ABSTRACT

In the study, the working conditions that challenged the employees during the assembly process in a factory where a belt conveyor was manufactured were analyzed using the REBA method. As a result of the evaluations, these challenging working postures were examined in seven stages. It was observed that the employees performed the assembly process primarily in squatting and heavily leaning postures. While the REBA score was recorded as 2 in the six stages related to assembling the carrier rollers onto the chassis of the conveyor belt, the highest REBA score, 13, was found in the seventh stage, which involved assembling the electric motor. It was recommended that the assembly operations be conducted on a movable platform with adjustable length and height, and that an additional platform capable of horizontal movement be used during the assembly of the electric motor. This approach would improve the risk protect for workers and help safeguard their health.

Keywords: *Belt conveyor assembly, REBA method, Worker posture evaluation, Ergonomic risk analysis*

INTRODUCTION

Professionals working in the field of ergonomics investigate topics such as risks involved in work activities, posture-related load, the effects of vibration, tool usage, connections, improper postures, the frequency and duration of movements, work irregularities, and the design of ergonomic workstations (Joshi and Deshpande, 2019).

Work-Related Musculoskeletal Disorders are prevalent in industrial settings, particularly where employees are engaged in physically demanding tasks. The

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occurrence and nature of these disorders vary significantly across different sectors (Storheim and Zwart, 2014).

Musculoskeletal disorders are among the most prevalent occupational challenges in both developed and developing nations, significantly impacting the industrial and service sectors. They contribute to higher healthcare expenses, increased wage compensation, reduced productivity, and a lower quality of life. Annually, these disorders affect billions globally. Work-related musculoskeletal disorders (WMSDs) arise from the interaction of multiple risk factors and can be classified into individual, psychosocial, and physical categories (Al Madani and Dababneh, 2016). The primary cause of WMSDs is repetitive stress that accumulates over time (Joshi and Deshpande, 2020). The global prevalence of musculoskeletal disorders (MSD) is reported to range from 14% to 42% (Sharma, 2012). Industries, particularly in developing countries with abundant and low-cost labor, heavily depend on human labor. However, this focus on cost reduction often leads to the neglect of ergonomic conditions. This underscores the importance of raising awareness about ergonomic risks, identifying their root causes, and implementing effective preventive measures. Without such precautions, employees are exposed to varying degrees of risk-ranging from low to very high-depending on the intensity and nature of their work. Ergonomic interventions are essential to minimize workers' exposure to high-risk factors, thereby reducing the prevalence of occupational diseases and workplace health and safety concerns. Ultimately, these efforts aim to optimize workers' health, safety, and productivity while improving their comfort, aligning with the core objective of ergonomics (Niu, 2010).

The REBA (Rapid Entire Body Assessment) method is one of the most widely recognized and commonly utilized observational ergonomic assessment tools across diverse industries and service sectors. Among all ergonomic assessment methods, REBA is highly generalized and broadly applied in many sectors (Hita-Gutiérrez *et al.*, 2020). It is a practical tool designed to evaluate the entire body, providing a numerical representation of the risk associated with specific working postures or movements (Çoker and Selim, 2019).

In our country, studies have been conducted on the posture analysis of workers in various sectors using the REBA method. It has been applied in replication tasks at the Trabzon-of forest nursery in the agricultural sector (Ünver-Okan and Kaya, 2015) and in corn production (Geniş and Sümer, 2021), in the construction sector (Obuz, 2016), in cable manufacturing factories (Ulutaş and Gündüz, 2017), in expansion tank manufacturing in the metal industry (Özoğul *et al.*, 2018), on combi boiler assembly lines (Gürleyen and Kahya, 2018), in bolt manufacturing factories (Sever and Deste, 2021), in textile enterprises (Çoker and Selim, 2019) and (Akyol, 2022), in the production line of the heavy metal industry (Tarakçı *et al.*, 2020), in casting workshops (Erdemir and Eldem, 2020), in the food sector (Kılıç and Çetin, 2021)and (Baş and Yapıcı, 2020), in the automotive sub-industry (Cakmak and Esen, 2023), in the assembly process of hay rakes (Gönen *et al.*, 2017a), in transformer operations (Gönen *et al.*, 2017b), in elevator production (Oral *et al.*, 2018) and in bolt factories (Sever and Deste, 2021).

This study aims to improve the unsuitable postures observed during the assembly process of a conveyor belt, which is part of the product design of a micro-scale enterprise. No similar study has been encountered in the literature on this topic. Analyses were conducted to determine the strain and muscle activations experienced by workers during the assembly process. The workers' risk levels for Musculoskeletal Disorders (MSDs) were assessed using the REBA method.

MATERIALS and METHODS

An Ethics Committee Approval Certificate was obtained with the decision dated 28.06.2024 and numbered E.781681 from the Scientific Ethics Review Board of Selçuk University Faculty of Agriculture.

The research was conducted in 2024 at KDM Makina, a company located in Konya, Turkey. The firm manufactures belt conveyors in various sizes. This is a micro-scale enterprise with a total of three workers, all of whom are involved in the assembly process.

The belt conveyor examined in this study was manufactured for a foundry, where it transports sand from the bunkers to the molding machine. The conveyor is 3 000 mm in length and 1 080 mm in width, with a belt width of 800 mm. A schematic view of the belt is provided in Figure 1. During the production phase, all connection holes in the chassis were cut using a laser, and the chassis was bent using a press brake. The assembly consists solely of bolt-nut connections.

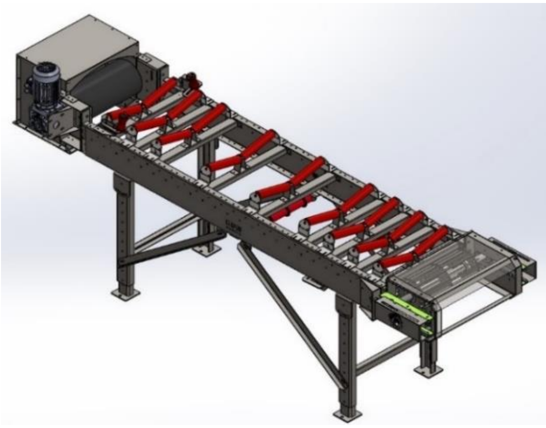


***Figure 1**. Schematic view of the belt chassis.*

Workers are exposed to Musculoskeletal Disorders (MSDs) during the assembly process. In the study, ergonomic analyses were conducted for the workers' postures during the production process of the conveyor belt, and their postures were evaluated using the REBA method. The assembly process was examined under seven sections. These stages are:

1. Initial assembly of the main chassis,
2. Connection of the roller side lugs to the main chassis,
3. Secondary assembly of the main chassis,
4. Assembly of the roller middle lugs
5. Mounting of drums,
6. Installation of the carrier rollers
7. Assembly of the electric motor

After these assembly operations, the installation of the belt conveyor and the belt are installed. In this study, ergonomic risks were evaluated using the REBA method, with all tables provided by Hignett and McAtamney (2000). The flowchart of the schematized REBA method is shown in Figure 2. According to this method, body parts are divided into two groups, A and B, when determining the REBA score.

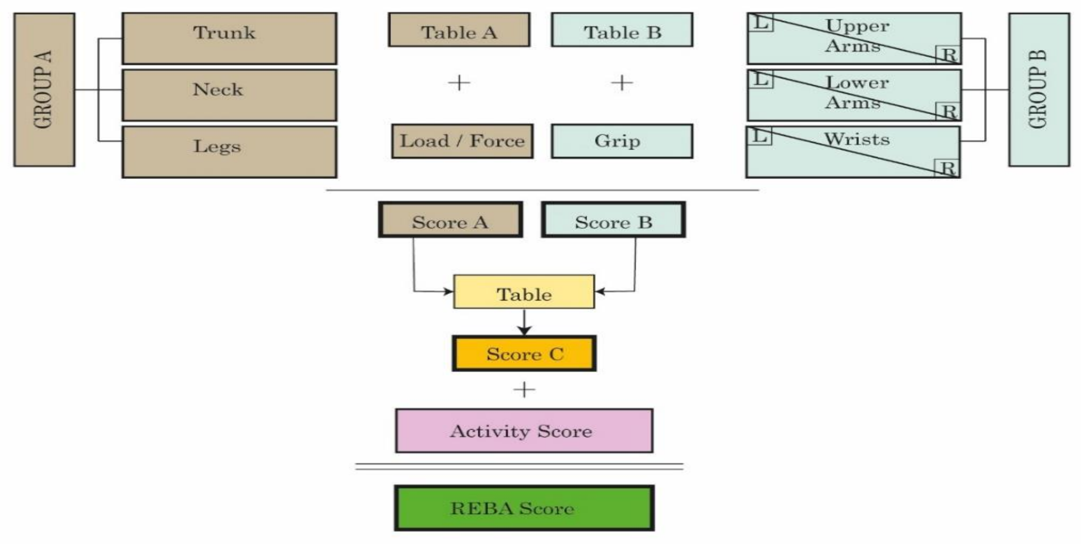
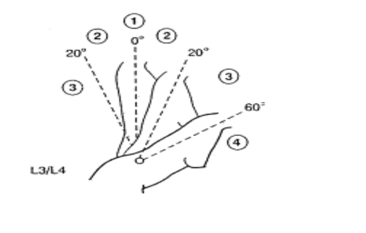
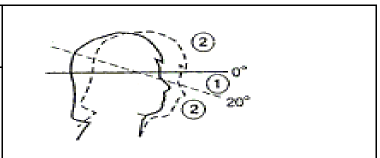


Figure 2. Flowchart of the REBA method.

Group A consists of limbs, trunk, neck and legs. Separate scores are determined for the trunk, neck and legs according to the worker's posture position (Figure 3). Using Table A, these individual scores, combined with the posture angles, are converted into a numerical format (Table 1).

Trunk			
Movement	Score	Change score	
Upright	1	+1 if twisting or side flexed	
0^0-20^0 flexion $>0^0$-20^0 extension	2		
20^0-60^0 flexion $>20^0$ extension	3		
$>60^0$ flexion	4		

Neck			
Movement	Score	Change score	
0^0-20^0 flexion	1	+1 if twisting or side flexed	
$>20^0$ flexion or extension	2		

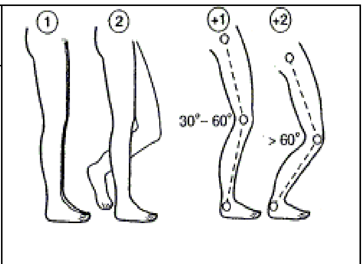
Legs			
Position	Score	Change score	
Bilateral weight bearing, walking or sitting	1	+1 if knee(s) between 30^0 and 60^0 flexion	
Unilateral weight bearing Feather weight bearing or an unstable posture	2	+2 if knee(s) are $>60^0$ flexion (n.b. Not for sitting)	

Figure 3. Diagram of group A body parts and corresponding scores.

After obtaining the numerical scores for Group A, the A score is calculated by adding the Load/Force score provided in Table 2 (Table 1).

***Table 1**. REBA method: Group A.*

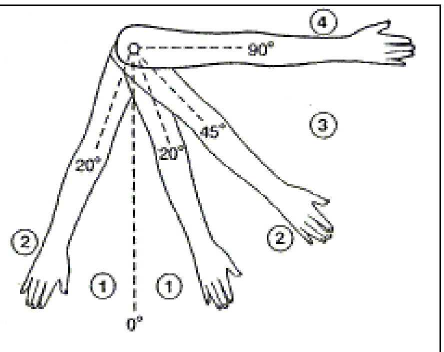
Table A	Neck												
		1				2				3			
	Legs												
		1	2	3	4	1	2	3	4	1	2	3	4
Tınk Poisture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

***Table 2**. Load / Force score.*

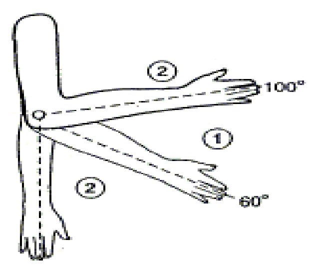
0	1	2	+1
<5 kg	5-10 kg	>10 kg	Sock or rapid build uo of force

Group B consists of upper arms, lower arms and wrists. According to the REBA method, separate scores are determined for the upper arm, lower arm, and wrist for both the right and left limbs simultaneously, based on the worker's posture, as shown in Figure 4.

Upper arms		
Movement	Score	Change score
20^0 extension to 20^0 flexion	1	+1 arm is: abducted, rotated
$>20^0$ extension 0^0-20^0 flexion	2	+1 if shoulder is raised
45^0-90^0 flexion	3	-1 if leaning supporting weight of arm or if posture is gravity assisted
$>90^0$ flexion	4	



Lower arms	
Movement	Score
60^0-100^0 flexion	1
$<60^0$ flexion or $>100^0$ flexion	2



Wrists		
Movement	Score	
0^0-15^0 flexion/extension	1	+1 if the wrist are on either radial or ulnar deviation
$>15^0$ flexion/extension	2	

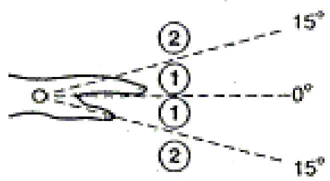


***Figure 4.** Diagram of group B body parts and corresponding scores.*

The first step in determining the Group B score is to combine the arm and wrist angle score values from the table (Table 3). To calculate the final B score, the grip score value provided in Table 4 is added to the Group B score.

Table 3. *REBA method: Group B table.*

Table B	Lower arm					
		1			2	
	Wrist					
		1	2	3	1	2	3
Upper Arm Score	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

Table 4*. Grip score.*

0 Good	1 Fair	2 Poor	3 Unacceptable
Well-fitting handle and a mid-rage, power grip	Hand hold acceptable but not ideal or coupling is acceptable via another part of body	Hand hold not acceptable although possible	Awkward unsafe grip, no handles Coupling is un acceptable using parts of the bady

The A and B scores obtained from the REBA flow chart (Figure 1) are combined using the C Table, as shown in Table 5. This process yields the final C score in the method.

Table 5*. REBA method C table.*

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

There is a lack of information regarding whether the task is performed in a moving or stationary position. This gap is addressed by adding the activity score of the worker to the C score obtained (Table 6).

Table 6*. Activity score.*

+1	1 or more body parts are static, e.g. held for longer than 1 min
+1	Repeated small range actions, e.g. repeated more than 4 times per minute (not including walking)
+1	Action causes rapid large range changes in postures or an unstable base

A REBA score is obtained by adding the activity score to the C score. The ergonomic risk assessment of the working conditions is then performed using the resulting REBA score. This score is evaluated according to the REBA risk rating table, shown in Table 7. The REBA risk rating consists of 5 levels, ranging from 0 to 4, with scores separated by numerical values from 1 to 15. The ergonomic risk assessment of the working conditions is determined based on the obtained REBA score.

Table 7. *REBA score table.*

Action level	REBA score	Risk level	Action(including further assessment)
0	1	Negligible	None necessary
1	2–3	Low	May be necessary
2	4–7	Medium	Necessary
3	8–10	High	Necessary soon
4	11–15	Very high	Necessary now

RESULTS and DISCUSSION

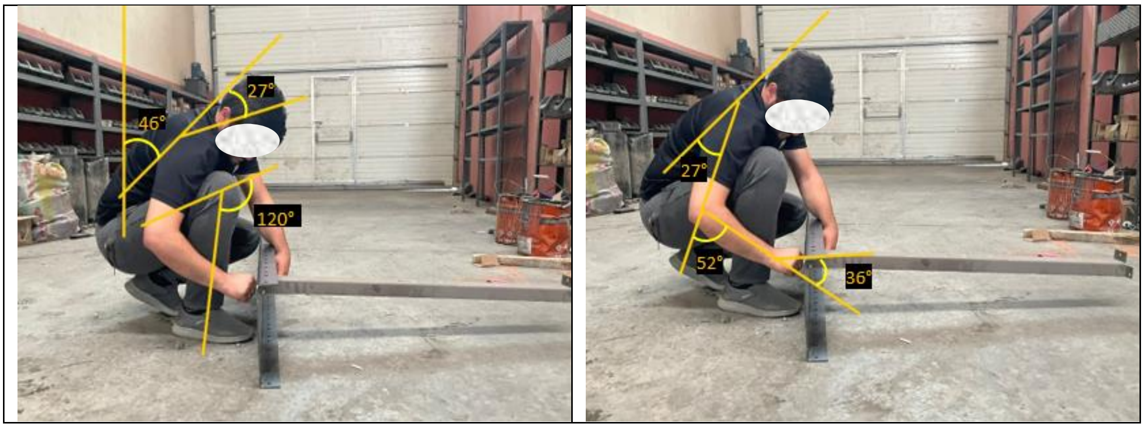
The ages, weights, and heights of the three workers employed in the micro-scale enterprise were determined as 37, 32, and 24 years; 65, 85, and 80 kg; and 171, 178, and 172 cm, respectively. Additionally, their work experience is 2, 2, and 3 years, and their educational background includes one primary school graduate and two high school graduates.

During the assembly of the belt conveyor, REBA analysis was conducted based on the process steps, assessing the body, neck, leg, upper and lower arm, and wrist postures. The REBA analysis results obtained during the initial connection of the main chassis are shown in Table 8.

At the start of the main chassis assembly, the worker works in a squatting position, placing the greatest strain on the body, as indicated in Table A. In this study, the REBA score was determined to be 5, indicating a medium risk level. Precautionary measures are necessary for this work posture, which is maintained throughout the day.

Table 8. *Initial assembly of the main chassis.*

<table>
<tr><td colspan="2">Group A</td><td>Table A</td><td colspan="2">Group B</td><td>Table B</td></tr>
<tr><td>Body</td><td>3</td><td rowspan="4">5</td><td>Upper arm</td><td>2</td><td rowspan="4">3</td></tr>
<tr><td>Neck</td><td>2</td><td>Lower arm</td><td>2</td></tr>
<tr><td>Legs</td><td>2</td><td>Wrist</td><td>2</td></tr>
<tr><td>Load/Force</td><td>-</td><td>Clutch</td><td>-</td></tr>
<tr><td>A score</td><td colspan="2">5</td><td>Score B</td><td colspan="2">3</td></tr>
<tr><td colspan="3">C score</td><td colspan="3">4</td></tr>
<tr><td colspan="3">Activity score</td><td colspan="3">1</td></tr>
<tr><td colspan="3">REBA score</td><td colspan="3">5</td></tr>
<tr><td colspan="3">Degree</td><td colspan="3">2</td></tr>
</table>

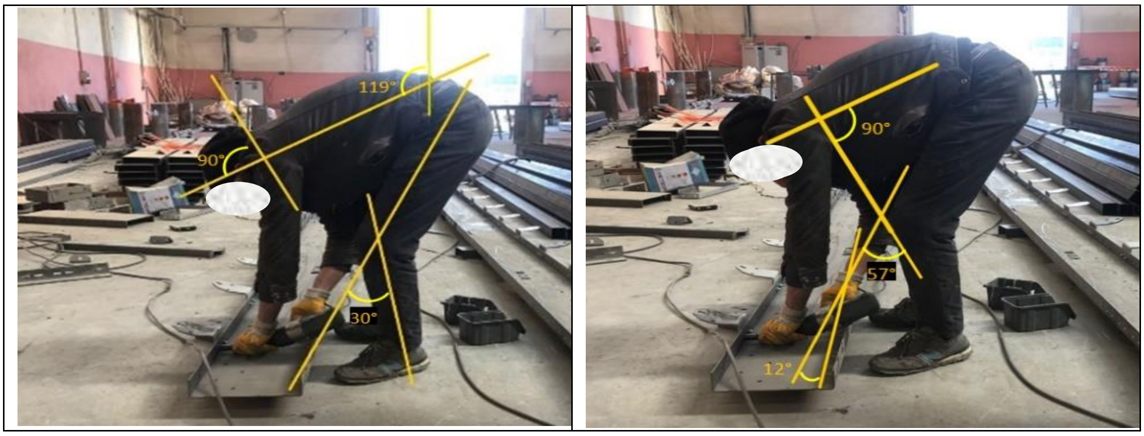


The results obtained from connecting the roller side lugs to the main chassis are shown in Table 9. In this position, the work is performed on the floor with the worker standing and bent over, and the task is repeated throughout the day. In this process, the greatest strain occurs in the trunk and upper arms. By adding the activity score (2) to the obtained C score (5), the REBA score was determined to be 7. The risk level for this working posture is medium, and precautions are required to improve this posture. Oral *et al.* (2018) reported that marking the belt holes of a bucket elevator was performed on the ground, with a REBA score of 10 determined for this task. Due to the high frequency of repetitive movements during this assembly process, it is necessary for workers to rotate tasks. This approach would help reduce the repetitive movements performed by the workers.

As observed in Table 8 and Table 9, workers perform these assembly processes on the ground. Strains are evident in their trunks, neck, and legs. Özoğlu *et al.* (2017) determined a REBA score of 8 for the task of packaging metal washers and reported that the lack of an appropriately elevated press bench caused strain in the lower back, upper back, and arms. Gönen *et al.* (2017b) found that during transformer assembly, workers experienced significant strain in the trunk, neck, legs, and upper arms due to squatting and bending postures, with a REBA score of 12. İn another research, Erdemir and Eldem (2020) conducted an ergonomic analysis of work postures during the ladle preparation stage in a foundry using the REBA method and identified a REBA score of 10.

Table 9*. Connection of the roller side lugs to the main chassis.*

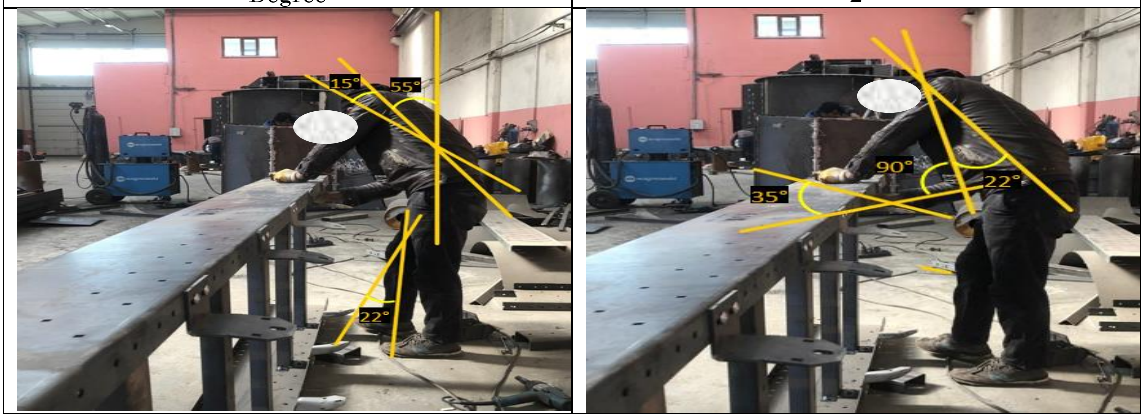
Group A		Table A	Group B		Table B
Body	4	5	Upper arm	3	4
Neck	1		Lower arm	2	
Legs	2		Wrist	1	
Load/Force	-		Clutch	-	
A score	5		Score B	4	
C score			5		
Activity score			2		
REBA score			7		
Degree			2		



In the third stage, the connection of the main chassis is completed. The A (5) and B (2) scores for the two main chassis, joined by bolts and nuts, were matched in the C table, resulting in a score of 4 (Table 10). With the addition of the activity score, the REBA score was determined to be 5. The risk level for this task falls within the range of 4-7, indicating a medium risk level. As per the REBA guidelines, precautions should be taken to mitigate the risks associated with this posture.

***Table 10**. Second assembly of the main chassis.*

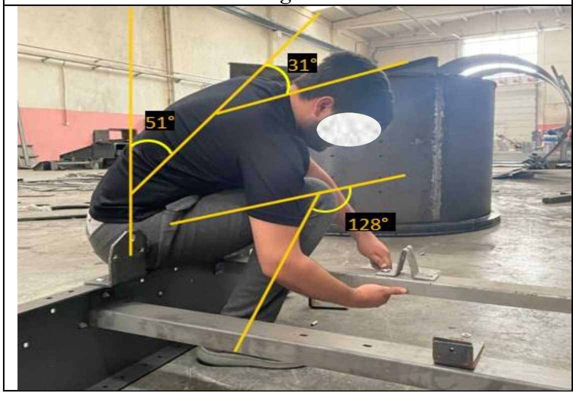
Group A		Table A	Group B		Table B
Body	4	5	Upper arm	2	2
Neck	1		Lower arm	1	
Legs	2		Wrist	2	
Load/Force	-		Clutch	-	
A score	5		Score B	2	
C score			4		
Activity score			1		
REBA score			5		
Degree			2		



The REBA analysis of the roller middle lug connection in the fourth stage is shown in Table 11. It is observed that the trunk, legs, upper arms, and wrists experience significant strain during this assembly. After adding the activity score to the C score, the REBA score was determined to be 8. This score indicates a high-risk level, and precautions should be taken promptly.

***Table 11**. Reel middle lug assembly.*

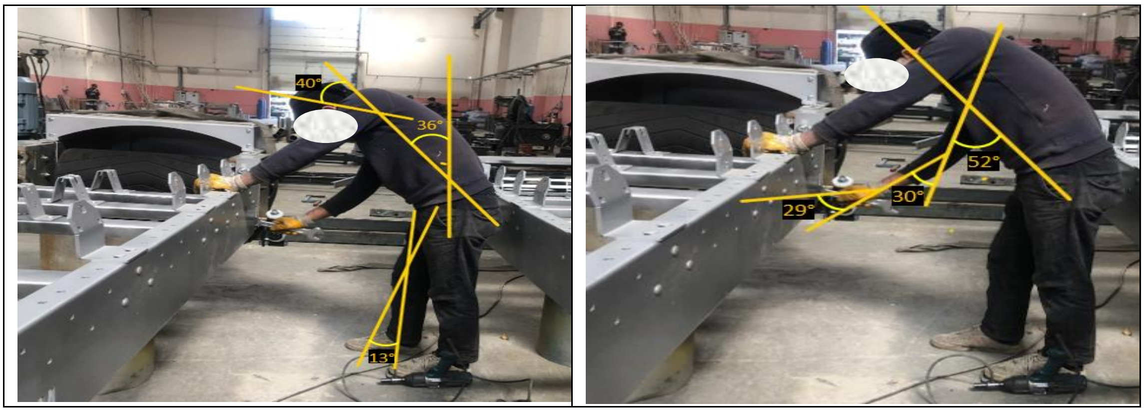
Group A		Table A	Group B		Table B
Body	3	6	Upper arm	3	4
Neck	2		Lower arm	1	
Legs	3		Wrist	2	
Load/Force	-		Clutch	-	
A score	6		Score B	4	
C score			7		
Activity score			1		
REBA score			8		
Degree			3		



The REBA score table determined in the fifth assembly stage, which involves connecting the drums to the chassis, is shown in Table 12. Upon examining the relevant table, the Table A score was found to be 5 by evaluating the leg, neck, and trunk posture positions. The B score was determined by assessing the lower arm, wrist, and upper arm posture positions, resulting in a score of 5. Based on these scores, the C score was calculated to be 6. After adding the activity score, the REBA score was determined to be 8. Considering the risk level range, this score falls within the high-risk category (8-10). According to the REBA guide, precautions should be taken promptly. Aksüt *et al.* (2020) reported that hand-operated workers in the industrial sector are exposed to critical physical strain that leads to musculoskeletal disorders, with lifting, poor posture, and repetitive movements identified as the primary causes of these disorders. Therefore, it is necessary to improve the posture during the drum connection process.

***Table 12**. Drum connection.*

Group A		Table A	Group B		Table B
Body	3	5	Upper arm	3	5
Neck	2		Lower arm	2	
Legs	2		Wrist	2	
Load/Force	-		Clutch	-	
A score	5		Score B	5	
C score			6		
Activity score			2		
REBA score			8		
Degree			3		



The worker stands while assembling the conveyor belt on the chassis of the carrier rollers (Table 13). The A, B, and C scores were found to be 4, 1, and 2, respectively, resulting in a REBA score of 2. The risk level for this working position was determined to be low, with a risk degree of 1. While the risk is low, precautions may still be required. Ayan (2015) determined a REBA score of 2 for flywheel assembly in the automotive sector. The aforementioned assembly stages should be performed on a platform.

Table 13. *Mounting of carrier rollers.*

Group A		Table A	Group B		Table B
Body	2	4	Upper arm	1	1
Neck	2		Lower arm	1	
Legs	2		Wrist	1	
Load/Force	-		Clutch	-	
A score	4		Score B	1	
C score			2		
Activity score			-		
REBA score			2		
Degree			1		

In the final stage of the assembly, the electric motor is mounted (Table 14). Upon examining Table 14, the A score was found to be 8, and the B score was 7. When the A and B scores were matched in the C table, the score was determined to be 10. With the addition of the activity score, the REBA score for the electric motor assembly was calculated as 13. This score corresponds to a degree of 4, indicating a very high-risk level, and according to the REBA guidelines, immediate action must be taken.

In the final stage of assembly, the electric motor is installed (Table 14). Upon examining Table 14, the A score was determined to be 8 and the B score was 7. When the A and B scores were matched in Table C, the score was determined to be 10. With the addition of the activity score, the REBA score for the electric motor assembly was calculated to be 13.

This score corresponds to a degree of 4, indicating a very high-risk level, and according to the REBA guidelines, immediate action must be taken.
At this stage, the assembly of the electric motor should be carried out on a platform equipped with a slide system capable of horizontal movement.

Table 14. *Mounting of electric motor.*

Group A		Table A	Group B		Table B
Body	3	5	Upper arm	3	5
Neck	2		Lower arm	2	
Legs	2		Wrist	2	
Load/Force	3		Clutch	2	
A score	8		Score B	7	
C score			10		
Activity score			1		
REBA score			13		
Degree			4		

During the assembly of the drum, roller, and electric motor, the belt chassis is placed on a support from both sides. There is a high risk of workplace accidents if any falling incident occurs during the operation.

CONCLUSION

In the study, the production process of a belt conveyor was examined in seven defined stages. The REBA method was used to analyze potential strain on the workers. Excessive loads during assembly were found to cause Musculoskeletal Disorders (MSDs). The lowest REBA score, 2, was recorded during the assembly of the carrier rollers onto the conveyor belt chassis, while the highest REBA score, 13, was recorded during the assembly of the electric motor. The risk level for roller installation was identified as low, whereas the risk level for electric motor installation was determined as very high. Medium and high-risk levels were identified in the working conditions of the other assembly stages. Considering the working conditions, it was concluded that assembly operations should not be performed on the ground but rather on platforms with adjustable length and height. Furthermore, although lifting tasks during the assembly of the drum and electric motor were performed using a crane, it is recommended that the electric motor assembly be carried out on a secondary platform equipped with a slide system capable of horizontal movement. The use of such platforms would reduce risks, prevent unnecessary muscle movements, protect workers' health, shorten production time, and result in cost savings.

Additionally, it is evident that ergonomic training sessions need to be provided within the scope of occupational health and safety (OHS). Thus, workers should be informed about the necessity of correcting their leg postures and avoiding wrist twisting.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The author declared that the following contributions is correct.

Haydar HACISEFEROĞULLARI: Investigation, methodology, conceptualization, formal analysis, validation, writing-orginal draft, review and editing
Hasan ŞAŞKIN: Data curation, formal analysis, validation, writing, visualization

ETHICS COMMITTEE DECISION

An Ethics Committee Approval Certificate was obtained with the decision dated 28.06.2024 and numbered E.781681 from the Scientific Ethics Review Board of Selçuk University Faculty of Agriculture.

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