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ERGONOMIC WORK FACILITY DESIGN USING ANTHROPOMETRIC DATA

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Abstract
This study aims to design an ergonomic study table based on students' anthropometric data to reduce the risk of musculoskeletal injuries. Anthropometric data, such as sitting elbow height, knee height, thigh length, and hand reach, were collected from 121 students using an anthropometer. In addition, musculoskeletal complaints were evaluated using the Nordic Body Map (NBM). Ergonomic risks were assessed using REBA (Rapid Entire Body Assessment) and RULA (Rapid Upper Limb Assessment) methods to identify non-ideal work postures. The results of the analysis showed that the current working posture of the students was in the high to very high risk zone, with a final REBA score of 9 and RULA of 8. Based on these results, an ergonomic study table was designed with adjustable height features (60-72 cm), 62 cm table width, and 124 cm table length. This design refers to anthropometric data with the 5th to 95th percentile range to ensure comfort and compatibility with various student body dimensions. This ergonomic study table design is expected to reduce the risk of musculoskeletal injuries, increase productivity, and create a healthier and more comfortable learning environment for students. Design validation through hands-on testing is a recommendation for further research.

Keywords: *Workbench design, anthropometric data, students, productivity, injury risk, ergonomic design*

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Introduction

In an era of increasingly competitive education, students' comfort and health while studying are major concerns. Students often spend hours studying at desks that are not in accordance with their body proportions. As a result, many of them experience health problems, especially musculoskeletal injuries due to posture. non-ideal body. This condition not only reduces productivity but also has a negative impact on the quality of life of students.[1], [2]

Unfortunately, many study furniture available on the market are designed generically without considering the variation in body size of users, especially Indonesian students. Inappropriate table dimensions and the lack of ergonomic features, such as adjustable height or storage space that supports good posture, are major obstacles in creating an optimal study environment. In fact, ergonomic study facility design is very important to support comfort, increase efficiency, and prevent long-term health problems.[2], [3], [4]

Ergonomics, which is the science of adapting the work or learning environment to human needs and abilities, is the main approach in this study. One of the analytical tools used is the REBA (Rapid Entire Body Assessment) and RULA (Rapid Upper Limb Assessment) methods. Both methods are used to identify the risk of musculoskeletal injuries due to non-ergonomic work postures. The results of this analysis are the basis for designing ergonomic work desks that suit the needs of students.[5], [6]

An anthropometric-based approach is the mainstay of this research. Data such as sitting elbow height, knee height, thigh length, and hand reach are used to ensure a desk design that supports a comfortable working posture. With ergonomic design, the risk of musculoskeletal injuries can be minimized, productivity increased, and the student learning environment becomes more supportive.[7], [8]

This study aims to design an ergonomic study table that is in accordance with students' anthropometric data, as well as reducing the musculoskeletal risks identified through the REBA and

RULA methods. This design is expected to be a solution to create a healthier, more comfortable, and efficient learning environment.

Research Method

This study uses a descriptive approach with the aim of explaining solutions to ergonomic problems in the student learning environment. The object of the study was Industrial Engineering students of Andalas University, with a sample size of 121 people. The data collected included student anthropometric data and musculoskeletal complaints using the Nordic Body Map (NBM).

Anthropometric data collection was carried out using an anthropometer measuring instrument, which includes sitting elbow height, knee height, thigh length, and hand reach. This data is used as a basis for designing an ergonomic study table that fits the user's body dimensions.

Musculoskeletal complaints were assessed using the Nordic Body Map with four Likert scales to identify body parts experiencing discomfort [9]. Data analysis was performed using IBM SPSS version 27 and Microsoft Excel software to generate information related to the distribution of anthropometric data and levels of complaints.[10]

The results of the musculoskeletal complaint analysis and anthropometric data were then used to design an ergonomic study table. The table design considers ideal dimensions based on the 5th to 95th percentile to ensure comfort and compatibility with most users. Key features in the design include adjustable table height, adequate table width, and ergonomic workspace.

The REBA and RULA method-based approaches were used to evaluate ergonomic risks before and after the implementation of ergonomic desk design. The results of this evaluation are expected to support the validation of the effectiveness of the design in reducing the risk of musculoskeletal injuries.[11]

Results and Discussion

A. Nordic Body Map (NBM)

The level of student complaints when studying, especially using laptops, with various positions including sitting on the floor with a laptop underneath, sitting on a chair with a table, lying down with a laptop on your thighs, and sitting cross-legged with a laptop on a table. It can be seen based on the results of the Nordic Body Maps (NBM) [12]as follows:

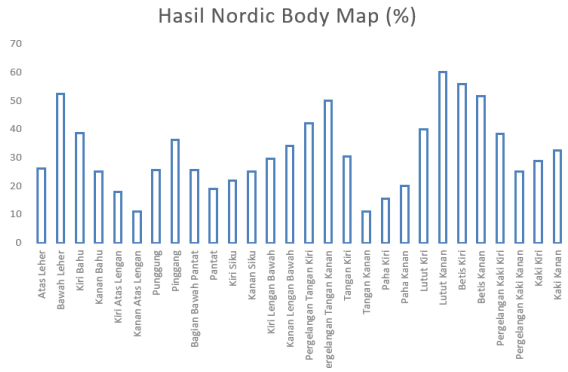

Figure 1Nordic Body Map

(Source: Data processing)

Based on observations using the Nordic body map, it can be concluded that in general, the average student experiences complaints in various parts of the body such as the neck, shoulders, back, and legs. This pain can be associated with the working position adopted by the students, including High complaints in the supine position or sitting on the floor with a laptop below, the neck forms an angle of >20°. The back and waist often experience postural loads with an angle of >20°. The position of the feet is stable when sitting cross-legged, but higher complaints when lying down. The average

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score obtained from 10 samples was 7, reflecting a high level of risk. Therefore, corrective actions need to be taken immediately to reduce this risk .Results are the main part of scientific articles, containing: clean results without data analysis process, results of hypothesis testing. Results can be presented with tables or graphs, to clarify the results verbally.

Discussion is the most important part of the overall content of scientific articles. The objectives of the discussion are: Answering research problems, interpreting findings, integrating findings from research into existing knowledge sets and developing new theories or modifying existing theories.

B. REBA (Rapid Entire Body Assessment)

1. Group A

Group A in the REBA method consists of scoring the neck, trunk, and legs. Analysis in Group A shows that the neck often experiences excessive load when lying down or sitting on the floor, with an angle of >20° which increases the risk of injury (REBA score 2). The back and waist show significant complaints due to body posture that forms an angle of >20°, especially when lying down, resulting in a REBA score of 4. In addition, leg stability is also affected, with the lying down position showing higher complaints than sitting cross-legged, giving a REBA score of 2. Overall, the total REBA score for Group A is at a score of 6.

Table 1Group A Scores (REBA)

		Neck											
		1				2				3			
	Legs												
		1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture 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

(Source: [12])

2. Group B

Group B in the REBA method consists of scoring the upper arm, lower arm, and wrist. In Group B, the upper arm shows high complaints in positions such as lying down with a laptop on the thigh, due to an angle of >45°, with a REBA score of 3. The lower arm, which often forms an angle of >100° in a similar position, has a REBA score of 2. The wrist shows high complaints due to extreme rotation or reach, especially in positions other than sitting with an ergonomic desk, resulting in a REBA score of 2. The total score for Group B ranges from 5, indicating ergonomic risks that need to be addressed.

Table 2Group B Scores (REBA)

		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

(Source: [12])

3. REBA final score

The next step, enter the final scores of tables A and B into table C. The final score of REBA will produce the results of the work posture.

a) Score A is obtained by 5 plus a load of <5 kg and the activity is done repeatedly, so that the total score of table A is = 6+0+1 = 7. So in the score table A, the number 7 is circled.
b) Score B is obtained by 6 plus a load of <5 kg and the activity is done repeatedly, so that the total score of group B is = 5+0+1 = 6. So in the score table B is circled the number 6.

The final REBA score can be seen in table 3 where it was found that the REBA score of workers before the implementation of improvements was 9. This score indicates that the posture of students when studying at home without using a suitable table has a high level of ergonomic risk and needs to be immediately improved in the students' posture to reduce the risk of injury or discomfort while studying.

Table 3Total Score (REBA)

Score A	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

(Source: [12])

C. RULA (Rapid Upper Limb Assessment)

1. Group A Scores

Group A in the RULA method consists of scoring the arms and wrists. The upper arm gets a score of 4, because the upper arm forms an angle of >45°. The lower arm gets a score of 3, because the lower arm forms an angle of >100° and the arms are crossed. The wrist gets a score of 4, because the wrist posture is in extreme rotation when typing or using a mouse, especially when in a position without a desk. For wrist rotation, a score of 1 is given, because the wrist rotates in the middle range. Furthermore, the total score of group A is determined based on the RULA guide which can be seen in the following table.

Table 4Group A Score (RULA)

Table A		Wrist Score							
		1		2		3		4	
Upper Arm	Lower Arm	Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	3	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

(Source: [13])

The results showed that the total score of group A (upper arm, lower arm, and wrist) got a total score of 6.

2. Group B Scores

Group B in the RULA method consists of scoring the posture of the neck, body, and legs. For the neck, it gets a score of 4, because the neck angle is more than 20°, often occurs when looking at the laptop below or in an unergonomic position. For the body, it gets a score of 4, because the body angle is more than 20°, especially in a stretched or bent position. For the legs, it gets a score of 2, because of the imbalance in the leg posture, especially when sitting on the floor or stretching.

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Furthermore, the total score of group B is determined based on the RULA guide which can be seen below.

Table 5Group B Score (RULA)

Neck Posture Score	Table B: Trunk Posture Score											
	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

(Source: [13])

The results showed that the total score of group B (neck, body, legs) got a total score of 7.

3. Total RULA Score

Determining the total RULA score is done by entering scores A and B into table C. The final value of RULA will produce the results of the work posture.

a) Score A is obtained by 6 plus a load of <5 kg and the activity is done repeatedly, so that the total score of table A is = 6+0+1 = 7. So in the score table A, the number 7 is circled.
b) Score B is obtained by 7 plus a load of <5 kg and the activity is done repeatedly, so that the total score of group B is = 7+0+1 = 8. So in the score table B is circled the number 8.

Based on data analysis using the RULA method, With Group A score = 7 and Group B = 8, the RULA combination table produces a final score of 7. This score indicates a very high risk, and corrective action for work posture must be taken immediately to prevent musculoskeletal injuries. The calculation of the total RULA score results can be seen in the following table.

Table 6Total Score (RULA)

Table C		Neck, Trunk, Leg Score						
		1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

(Source: [13])

D. Anthropometric Data

The following are the results of data collection through anthropometric measurements of 121 students:

Table 7Student Anthropometric Data

		Percentiles		
Measurement	SD	5	50	95
Sitting Elbow Height	3.54	60.22	66.31	71.60
Knee Height	2.70	45.90	50.53	54.56
Thigh Length	2.61	44.42	48.90	52.80

Forward hand reach	3.87	66.62	73.35	79.16
Height	8.71	148.05	163.00	176.00

(Source: Data processing)

E. Data Normality Test

In the normality test of anthropometric data, the confidence level used is 95% and α = 0.05. The use of a 95% confidence level is because this value provides a balance between precision and reliability. The results of the normality test of anthropometric data using SPSS with the *Kolmogorov Smirnov method* can be seen in the following table:

Table 8Data Normality Test

Tests of Normality			
	Kolmogorov-Smirnov [a]		
Measurement	*Statistics*	*df*	*Sig.*
Sitting Elbow Height	.074	121	.096
Knee Height	.074	121	.159
Thigh Length	.074	121	.158
Forward hand reach	.072	121	.197
Height	.074	121	.158

(Source: Data processing)

The results of the data normality test using the Kolmogorov-Smirnov method showed that all anthropometric measurement data had a significance value (Sig.) greater than 0.05. [14]This indicates that the data is normally distributed. Variables such as sitting elbow height (Sig. = 0.096), knee height (Sig. = 0.159), thigh length (Sig. = 0.158), forward hand reach (Sig. = 0.197), and height (Sig. = 0.158) all meet the criteria for normal distribution. With a consistent significance value above the threshold of 0.05, the null hypothesis stating that the data is normally distributed can be accepted for all variables.

F. Data Uniformity Test

Table 9Data Uniformity Test

Measurement	Average	SD	UCL	LCL	Information
TSD	66.15	3.54	76.78	55.52	Uniform
TL	50.41	2.70	55.81	45.01	Uniform
PP	48.79	2.61	54.01	43.57	Uniform
JTK	73.14	3.87	84.75	61.54	Uniform
TB	162.62	8.71	180.04	145.20	Uniform

(Source: Data processing)

The results of the data uniformity test on anthropometric measurements showed that all variables were within the statistical control limits, which were indicated by the average value of each measurement being between the upper control limit (UCL) and the lower control limit (LCL). Variables such as sitting elbow height (average = 66.15, UCL = 76.78, LCL = 55.52), knee height (average = 50.41, UCL = 55.81, LCL = 45.01), and other variables, were all declared uniform because no data exceeded the control limits.

This data uniformity indicates that the data does not contain excessive variation and is statistically stable. Data uniformity also reflects that data collection is carried out systematically and is free from significant errors.[15]

G. Data Adequacy Test

In the data adequacy test, the level of confidence used is 95% and the accuracy is 5%. The results of the calculation of anthropometric data adequacy with the following formula:

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$$N' = \left[\frac{\frac{k}{s}\sqrt{N\Sigma X^2 - \Sigma X^2}}{\Sigma X}\right]^2 \quad (1)$$

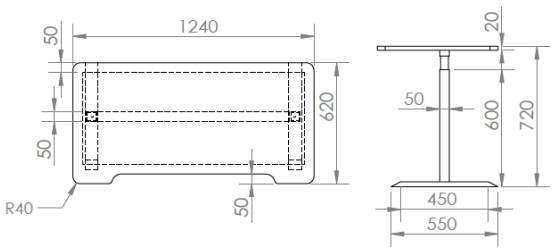
Table 10Data Adequacy Test

No	Measurement	N	N'	Description (N'<N)
1	Sitting Elbow Height	121	4.55	Sufficient Data
2	Knee Height	121	4.55	Sufficient Data
3	Thigh Length	121	4.55	Sufficient Data
4	Reach your hands forward	121	4.44	Sufficient Data
5	Height	121	4.55	Sufficient Data

(Source: Data processing)

Based on the data in the table above, the results of N' for each anthropometric data variable used indicate data adequacy because N'<N, which means that all data for each anthropometric data variable measured meets the data adequacy requirements.[16]

H. Ergonomic Work Desk Dimensions



2 Dimensional Image SEQ Gambar | ARABIC of Study Table*

Table 11Study Table Percentiles

No	Table dimensions	Size	Percentile%
1	Table Height	60-72cm	5-95
2	Table Width	62cm	95
3	Table Length	124cm	95

(Source: Data processing)

The selection of table dimensions in this study was based on students' anthropometric data, with the aim of creating a design that is comfortable and usable by most users [17], [18]. The table height is designed in the range of 60–72 cm, based on the 5th to 95th percentile. This range allows the table to be adjusted as needed, thus supporting good posture and reducing the risk of musculoskeletal disorders. The table width is set at 62 cm, using the 95th percentile data, to provide sufficient workspace for daily learning activities. Meanwhile, the table length is designed at 124 cm, also using the 95th percentile data, to ensure that users have adequate workspace, both for laptop

use, books, and stationery. With this approach, the table design not only focuses on comfort, but also supports the overall productivity and health of the user.

Figure 2Final Design of Study Table

I. Reba Score Comparison

score for posture after using an ergonomic desk obtained in actual conditions, the final REBA score is 9. This means that students have a high risk of experiencing musculoskeletal disorders, so efforts are needed to improve posture right now. After improving posture while studying using a desk based on the results of student anthropometric calculations, the final REBA score was 3 , with a Group A score of 3 because the neck position is more neutral and leg stability increases with the support of an ergonomic desk, and a Group B score of 2 because the arm posture is better because the arm angle approaches the neutral position. This means that students experience a decrease in the risk of musculoskeletal disorders and other muscle skeletal disorders. Comparison of REBA scores before and after improvement.

Table 12Comparison of REBA Scores

Information	Before use	After use
Group A Body Score	6	3
Group B Body Score	7	2
Grand score	9	3
Risk level	Tall	Low
Action	Improvements need to be made current job position	Low risk, changes may be necessary

(Source: Data processing)

J. RULA Score Comparison

RULA score for posture after the improvement obtained is in the actual condition, the final RULA score is 7. This means that employees have a high risk of experiencing musculoskeletal disorders, so efforts are needed to improve posture right now. After improving posture while working using a desk based on the results of student anthropometric calculations, the final RULA score is 3. This means that workers tend not to be at risk of experiencing musculoskeletal disorders and other muscle skeletal disorders. Comparison of RULA scores before and after improvement.

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Table 13comparison of RULA Scores

Information	Before use	After use
Group A Body Score	6	3
Group B Body Score	7	4
Grand score	7	3
Risk level	Tall	Low
Action	Improvements need to be made current job position	Low risk, changes may be necessary

(Source: Data processing)

Conclusion

The results of the analysis using the REBA and RULA methods showed that the work posture before the ergonomic desk design was in the high to very high risk zone. The final REBA score of 9 and RULA of 8 indicated that the body position, especially the neck, trunk, and arms, was very susceptible to musculoskeletal injuries. This is caused by an unergonomic work position, such as a neck and body angle that is too steep and wrists that are in extreme rotation.

As a solution, an ergonomic desk design was carried out based on students' anthropometric data. This desk design takes into account the user's body dimensions, such as sitting elbow height, knee height, thigh length, and hand reach forward, to create a desk that can accommodate various work postures optimally. Some of the main features of the desk design include:

- Adjustable table height in the range of 60–72 cm.
- The table width is 62 cm and the table length is 124 cm, to provide adequate work space.
- The design supports a neutral posture, reducing pressure on body parts such as the neck, back and arms.

After the simulation of using the ergonomic desk, the REBA score decreased to 3 (low risk zone), and the RULA score decreased to 3 (low risk zone). This decrease indicates that the ergonomic desk design can significantly improve body posture , especially in the neck, back, and arms.The conclusion should clearly indicate the results obtained, the advantages and disadvantages, and the possibility of further development. The conclusion can be in the form of a paragraph, it can also be in the form of points using numbering (Tahoma, 10pt, spaced 1.15).

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