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Analysis of Manual Router Operator Work Posture Using the REBA Method to Reduce the Risk of MSDs

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ABSTRACT

Manual router operators at PT Delapan Intan Mutiara perform tasks that require bending, reaching, and controlling a handheld tool during routine production at this workstation, potentially exposing them to ergonomic risks. This study aimed to identify musculoskeletal complaint levels among operators, determine the body regions contributing most to complaint scores, and assess the risk of one documented working posture. A descriptive quantitative approach was applied to all 13 operators using the Nordic Body Map (NBM) questionnaire, which assessed 28 body regions. One recorded working posture was evaluated using Rapid Entire Body Assessment (REBA), supported by angle measurements from Kinovea software. The total NBM score was 835. The waist contributed the highest score, 41 (4.91%), followed by the back, 39 (4.67%). Both upper arms and both wrists each scored 33 (3.95%). Eight operators (61.5%) were classified as having moderate complaint levels, three (23.1%) high, one (7.7%) very high, and one (7.7%) low. The reported REBA score for the assessed posture was 13, indicating very high postural risk and a need for prompt ergonomic evaluation. However, the load, grip, and activity adjustments require confirmation from field measurements, so this score remains provisional. The findings suggest prioritizing adjustable workbench height, secure material clamps, and tool guides to reduce bending and excessive reaching. This study contributes a practical baseline combining operator-reported complaints with observation of a specific posture, helping the company set improvement priorities. The effectiveness of proposed changes must be tested through follow-up assessments before any reduction in ergonomic risk can be confirmed.

Keywords: *Ergonomic, Manual Router Operator, Musculoskeletal Disorders, Nordic Body Map, Rapid Entire Body Assessment.*

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INTRODUCTION

Production work that involves the use of manual tools still poses risks to workers' muscle and joint health. These risks can arise when workers frequently bend over, reach up, grab objects at a distance, or make repetitive hand movements. If this continues over a long period, it can lead to pain in the back, waist, shoulders, and hands a condition known as musculoskeletal disorders (MSDs). This problem is also found in the wood processing industry. [1] A study of 167 wood furniture workers in Thailand showed that 58.68% of workers experienced musculoskeletal disorders, while 64.07% faced ergonomic risks in the form of poor work postures and heavy lifting. A study [2] of 60 wood-cutting workers also showed that 88.33% of workers were at a level of ergonomic risk requiring immediate action based on the Quick Exposure Check (QEC) method. These findings highlight the importance of ergonomic assessments in manual labor so that risky work conditions can be identified and corrected before they lead to more serious health problems.

A similar issue was observed among manual router operators at PT Delapan Intan Mutiara. Operators use manual routers to process materials, which involves movements of the hands, arms, neck, and torso. Based on initial observations, one operator was seen working in a standing position with a hunched posture and both arms extended beyond the work area. Measurements from the photograph showed a trunk angle of 65° and a neck angle of 28°. This posture indicates that the work conditions require review, as they may increase strain on the back, waist, and neck muscles. The company has 13 operators who served as study participants. However, preliminary data regarding the

duration operators maintain their body posture, movement frequency, material weight, and the magnitude of force exerted while working are not yet fully available. Therefore, an ergonomic assessment is necessary to identify the complaints experienced by operators and determine which work postures require attention.

Research on muscle strain and work posture risks has been conducted using various methods. [3] utilized the Nordic Body Map (NBM) and the Rapid Entire Body Assessment (REBA) on workers in the petrochemical industry. That study found musculoskeletal strain in the moderate to high categories, while certain material-handling activities received REBA scores of 11–12, indicating very high risk. Study [4] of 656 garment industry workers in Bangladesh used the Nordic Musculoskeletal Questionnaire (NMQ) and REBA. The results showed that 39.5% of workers reported lower back pain in the past 12 months. Of the 43 workers assessed using REBA, more than 53% fell into the high or very high-risk categories. Both studies demonstrated that workers' back pain reports and posture assessments can be used together to identify ergonomic issues. However, the observed tasks had different characteristics from manual router operation, which requires direct control of the tool through hand movements.

The selection of ergonomic assessment methods also requires consideration of their strengths and limitations.[5] A comparison of the OWAS, RULA, and REBA methods showed that risk assessment results can vary because each method uses different posture assessment rules.[6] A review of 99 studies and 75 observational methods explained that method selection must be tailored to the type of work and the risk factors to be assessed. This is important because complaint-based technology and posture assessment methods measure different things. NBM is used to record which body parts feel pain based on workers' responses, while REBA is used to assess risks from body position, load, grip, and observed work activities. Thus, a high complaint score does not always mean a high REBA score, and vice versa. Both methods should be understood as complementary tools, not as direct evidence that a particular posture has caused an illness.

Although previous studies have used complaint-based technology and posture assessment methods, there remains a need for research on more specific work conditions. Study [2] focused on wood-cutting workers using the QEC, while [3] examined activities in the petrochemical industry and [4] assessed workers in the apparel industry. These studies provide an important foundation for understanding ergonomic risks, but their results cannot be directly applied to determine the conditions of manual router operators at PT Delapan Intan Mutiara because the type of tool, work position, and activities differ. The research gap lies in the limited data [text unclear] regarding complaints about 28 body parts among all 13 operators, combined with the REBA assessment of manual router work postures documented at the study site. Additionally, there is currently no assessment framework available to identify the body parts and work conditions that require improvement by the company. These gaps are practical and contextual in nature; they do not stem from the fact that the NBM and REBA methods have never been used together.

The novelty of this study lies in the integrated presentation of two types of ergonomic information within the context of manual router work: the Kor scores for all operators based on NBM and the risk levels of specific work postures documented using REBA. This study not only identifies body parts with relatively high Kor scores but also links them directly to the body positions observed while operators are working. The results of both assessments were then used to develop preliminary recommendations for workplace improvements, such as adjusting table height, setting the distance to the workpiece, using support materials, and improving tool positioning. This approach provides a more accurate picture of the needs of manual router stations without assuming that workers' musculoskeletal disorders are caused by a specific posture.

Based on these issues and conclusions, this study aims to: calculate the total NBM score and determine complaint categories among 13 manual router operators; identify the body parts contributing the highest Kor scores out of the 28 measured body parts; and calculate and explain the risk level of documented work postures using the REBA method as the basis for determining ergonomic improvements. The study was conducted using the NBM questionnaire, work observations, and body angle measurements with the assistance of Kinovea software. The research results are expected to provide tangible benefits to the company in the form of information on operators requiring attention, the body parts with the highest complaint scores, and the postural conditions that the company should evaluate. This information can be used to design workstations that better suit operators' needs. However, this study is still limited to risk identification and assessment; therefore, the proposed improvements cannot be deemed successful until they have undergone direct testing.

METHOD

Research Design

This study used a quantitative descriptive approach to identify musculoskeletal complaints and assess the level of work posture risk among manual router machine operators at PT Delapan Intan Mutiara. The study combined the

Nordic Body Map (NBM) to describe the location and severity of complaints reported by workers with the Rapid Entire Body Assessment (REBA) to assess postural risk during a single documented activity. The results of both tools were interpreted descriptively as the basis for compiling ergonomic improvement recommendations. The study did not include the implementation of interventions or the measurement of changes in risk following improvements.

Study Population and Sample

The study population consisted of 13 liner production operators who operated manual routers. All members of the population were included using total sampling. The NBM questionnaire was used to collect complaint data from the 13 operators, while the REBA was conducted on a single work posture that had visual documentation and angle annotations. Therefore, the NBM results describe the surveyed respondents, while the REBA results are limited to the measured posture and are not considered scores for all operators.

Data Collection Techniques

Data collection was based on work observations, the NBM questionnaire, and visual documentation of manual router activities. Observations were aimed at identifying the positions of the torso, neck, arms, wrists, and legs, as well as job characteristics relevant to ergonomic risks. The NBM questionnaire recorded complaint levels across 28 body parts. Image documentation was analyzed using Kinovea to track the angles of body segments used in the REBA analysis.

Analysis of Complaints Using the Nordic Body Map (NBM)

The NBM covers 28 body parts, with scores ranging from 1 = no pain, 2 = mild pain, 3 = pain, and 4 = severe pain. An individual's score is calculated by summing the complaint scores for all body parts. For the 28 body parts, the theoretical score ranges from 28 to 112. Individuals are classified using the score thresholds summarized in Table 1.

$$S_i = \sum_{j=1}^{28} x_{ij} \quad (1)$$

In Equation (1), S_i is the total NBM score for the i-th operator, and x_{ij} is the complaint score for the i-th operator regarding the j-th body part.

Table 1. Classification of complaint risk levels using NBM

NBM total score	Risk categories
28–49	Low
50–70	Currently
71–91	Tall
92–112	Very high

The risk category distribution was calculated based on the number of operators in each category compared to the 13 respondents. The percentage contribution of a body part was calculated based on its total score relative to the cumulative total of all NBM scores from the 13 operators and 28 body parts. The distinction between these two types of percentages was maintained to ensure that the body part's score contribution was not mistakenly interpreted as the percentage of workers who complained.

$$K = \left(\frac{n_k}{N}\right) \times 100\% \quad (2)$$

$$P_j = \left(\frac{T_j}{T}\right) \times 100\% \quad (3)$$

In Equation (2), K is the percentage of respondents in a given category, n_k is the number of respondents in that category, and N = 13. In Equation (3), P_j is the percentage contribution of the jth body part score, T_j is the total score for that body part, and T is the total NBM score; in this dataset, T = 835.

Measuring Work Posture Angles Using Kinovea

Work posture angles are derived from photographs of operator activities using Kinovea. Relevant body segments include the torso, neck, legs, upper arms, forearms, and wrists. Anatomical landmarks and angle directions must be determined in accordance with the REBA measurement definitions; assessments can then be adjusted to account for rotation, lateral tilt, or differences in support conditions.

Postural Risk Assessment Using the Rapid Entire Body Assessment (REBA)

The REBA assessment is conducted in seven steps: (1) determine the scores for the trunk, neck, and legs; (2) combine them in Table A and add the load/force score; (3) determine the scores for the upper arm, forearm, and

wrist; (4) combine them in Table B and add the grip or coupling quality score; (5) combining the scores from Groups A and B in Table C; (6) adding relevant activity scores, such as documented static postures or repetitive movements; and (7) categorizing the final scores according to risk level and priority for action.

Table 2. Risk categories and action priorities according to REBA

REBA Score	Risk level	Need for action
1	Can be ignored	Not required
2–3	Low	It may be necessary
4–7	Currently	Required
8–10	Tall	Needed immediately
11–15	Very high	Needed as soon as possible

Integrated Analysis of NBM and REBA

The integrated analysis was conducted by comparing body parts that contributed relatively high NBM complaint scores with postural characteristics assessed using REBA. The interpretation is presented descriptively, noting that NBM recorded subjective complaints from 13 operators, while REBA assigned postural risk scores for a single activity.

Formulation of Ergonomic Improvement Recommendations

Recommendations were formulated by prioritizing dominant complaint areas and recorded postural risk components. Alternatives examined included adjusting work surface height, using material supports, adjusting hand reach and tool position, and evaluating grip quality. The proposals were presented as initial priorities whose feasibility must be assessed by the company.

Data Analysis Techniques

The analysis used descriptive statistics, including individual NBM scores, the frequency and percentage of complaint categories, and the contribution of complaint scores by body part. REBA assessments were presented as a series of posture scores for Group A, Group B, combined scores in Table C, additional activities, and final risk categories. The findings were then used to develop ergonomic control recommendations; the study did not employ hypothesis testing or causal analysis.

RESULT

A work posture assessment was conducted to determine the operator's body position while using a manual router at PT Delapan Intan Mutiara. Observations were made by examining the positions of the back, neck, arms, wrists, hands, and feet while the operator was working. Photographs of the work activities were analyzed using Kinovea software to help measure body angles. The measurement results were used as the initial basis for an ergonomic risk assessment using the Rapid Entire Body Assessment (REBA) method. The observed work postures and recorded body angles are shown in Figure 1.



Figure 1. Postures And Angle Annotations at The Manual Router Station

Based on Figure 1, the operator is seen working in a standing position with the body bent forward. Measurements show a torso angle of 65° and a neck angle of 28°. This position indicates that the operator must tilt the body and head toward the workpiece. If this position is maintained for too long or repeated frequently, the back and lower back muscles may be overworked, potentially causing fatigue and pain.

Regarding other body parts, the figure shows angles of 111° at the upper arm, 165° at the elbow, 19° at the wrist, and 122° at the ankle. The position of the arms extended forward and the hands adjusting the direction of the tool can increase the strain on the hand and shoulder muscles. Meanwhile, the misaligned position of the feet indicates the need for further examination of balance and body support while working. However, these angles still need to be verified based on measurement points in accordance with the REBA method.

Grade A

The assessment of work posture risk using the Rapid Entire Body Assessment (REBA) method begins with calculating the Group A score. This group consists of three body parts: the torso, neck, and legs. Each body part is scored based on the position and angles formed while the operator is working. These scores are then used with REBA Table A to determine the initial risk level of the operator's body posture. The process for determining the Group A score is shown in Table 3.

Table 3. REBA Table A used to determine the scores for Group A

		Neck											
	Leg	1	2	3	4	1	2	3	4	1	2	3	4
Body 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

Based on Table 3, the REBA calculation for Group A was performed by combining the scores for the torso, neck, and legs. The initial assessment results showed a torso score of 5, a neck score of 3, and a leg score of 4. These three scores were entered into Table A, resulting in a combined score of 9. This value indicates that the operator's body posture requires attention, as certain body parts are working in suboptimal positions. A high torso score is associated with the operator's hunched posture while using a manual router. This posture can increase the workload on the back and lower back muscles, especially if maintained for extended periods. Additionally, the downward-tilted neck position and the condition of the legs as they support the body also require attention to ensure the operator can work more comfortably.

In the initial calculation, Table A's score of 9 was added to a load score of 2, resulting in a final score of 11 for Group A. However, this additional load score still needs to be verified because data on the weight or force experienced by the operator is not yet available. The leg score also needs to be reconfirmed based on the position and placement of the feet during work.These results indicate that the operator's work posture needs to be evaluated, particularly regarding the position of the back, neck, and feet. Improvements can begin with adjusting the height of the workbench and the position of the workpiece so that the operator does not have to bend over excessively. The Group A score is then used in conjunction with the Group B score to determine the overall risk level using the REBA method.

Group B Score

After calculating the Group A score, the next step is to calculate the Group B score using the Rapid Entire Body Assessment (REBA) method. Group B consists of three body parts: the upper arm, the forearm, and the hand. The assessment is based on the position of each body part while the operator is using a manual router. Each body part is scored according to its position and angle of movement. These three scores are then used with Table B of the REBA to determine the risk score for the arm and hand. The process for determining Group B scores is shown in Table 4.

Table 4. REBA Table B for determination score group B

		Lower Arm 1		Lower Arm 2		
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

Based on Table 4, the results of the REBA calculation for Group B show that the miner's upper arm scored 5, the miner's lower arm scored 2, and the miner's hand scored 2. These three values were entered into Table B of the REBA, resulting in a combined score of 8. These results indicate that the operator's arm and hand positions require attention, as there are suboptimal body movements and postures during work.

The relatively high upper arm score is related to the operator's hand reaching for the workpiece. This position can cause the shoulder and arm muscles to work harder, especially if performed repeatedly. Additionally, the position of the forearm and hand as they adjust to the machine's direction can also increase the load on the muscles and joints. If this continues for a long time, it may cause fatigue and pain in the hands. In the initial calculation, the Table B8 score plus the "quality" score or couple of 2 resulted in a Group B score of 10. However, this additional score still needs to be verified because the condition of this tool has not been fully explained. Therefore, the score of 10 remains a preliminary result that must be confirmed through direct observation.

The results of this assessment indicate that the operator's arm and hand positions need to be corrected to reduce the risk of muscle and joint disorders. Improvements can be made by adjusting the distance of the workpiece to bring it closer to the operator, adjusting the machine's position, and ensuring that the equipment is comfortable and stable. Next, the Group B score is combined with the Group A score using Table C of the REBA to determine the overall risk level of the observed work posture.

Score C

After obtaining the scores for Group A and Group B, the next step is to calculate the combined score using Table C in the Rapid Entire Body Assessment (REBA) method. Score A indicates the risk associated with the position of the torso, neck, and legs, while Group B score indicates the risk associated with the position of the upper arms, forearms, and hands. These two scores are used to determine the overall risk level of the operator's work posture. The combined result is then added to the work activity score to yield the final REBA score. The process of combining Group A and Group B scores is shown in Figure 4.

Table 5.C REBA for combine score groups A and B

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

The calculation results show that Group A, the admirers, scored 11 and Group B scored 10. Both scores • were applied to Table C of the REBA, resulting in a score of 12. Next, a work activity assessment was conducted to determine whether there were additional conditions that could increase the risk to the operator's body.

In the REBA method, there are three conditions that can increase the activity score. First, an additional score of +1 is assigned if one or more body parts remain in the same position for more than one minute. Second, an additional score of +1 is assigned if the worker performs small, repetitive movements more than four times per minute. Third, an additional score of +1 is assigned if the work causes rapid and significant changes in body position or is performed with an unstable body base.

In this study, the initial calculation used an additional activity score of +1. This adjustment was made for the work of manual router operators, which involves fixed postures and hand movements while operating the tool. However, data on how long operators maintain a given body position and the number of movements per minute are not yet available. Therefore, the additional activity score of +1 still needs to be confirmed through direct observation to ensure it aligns with actual working conditions.

Summary of the REBA Assessment of Posture

Table 6 presents the results of the posture assessment of manual router operators using the REBA method, ranging from body angle measurements to the calculation of the final score. This summary is used to identify body parts at risk and to determine the level of risk and the priority of ergonomic improvements.

Table 6. Summary of REBA calculation components

Component	Angle/information	Score
Stem body	65°	5
Neck	28°	3
Foot	122°	4
Table A Score	Combination of components A	9
Score A after burden	9 + 2	11
Arm on	111°; 21°	5
Arm lower	165°; 53°	2
Wrist hand	19°; 61°	2
Table B Score	Combination of components B	8
Score B after coupling	8 + 2	10
Table C Score	A = 11; B = 10	12
Final REBA score	12 + 1	13

Based on Table 6, the assessment of manual router operators' work posture was conducted by measuring the positions of several body parts, namely the torso, neck, legs, upper arms, forearms, and hands. The initial assessment results showed that the torso had an angle of 65° with a score of 5, the neck had an angle of 28° with a score of 3, and the legs had an angle of 122° with a score of 4. These three values resulted in a Table A score of 9. After adding a load score of 2, a Group A score of 11 was obtained. These results indicate that the positions of the upper body and legs require attention, particularly because the operator works in a compromised position.

In Group B, the assessment focused on the positions of the arms and … hands. The upper arm has angle annotations of 111° and 21° with a score of 5; the forearm has angle annotations of 165° and 53° with a score of 2; while the hand has angle annotations of 19° and 61° with a score of 2. Combining these three scores using Table B yields a value of 8. After adding the "Quality" or "Coupling" score of 2, the Group B score is 10. This result indicates that the operator's arm and hand positions also need to be noted, especially when [Announcement] the object is in operation and the operator is holding the router.

Next, the Group A score of 11 and the Group B score of 10 are combined using Table C, resulting in a score of 12. This value is then added to the activity score of 1, resulting in a final REBA score of 13. Based on the REBA assessment categories, a score of 13 falls into the "very high" risk level.

Nordic Body Map (NBM) Analysis

Based on the NBM matrix in Figure 5, the total score for the 13 operators and 28 body parts is 835. The waist has a score of 41, or 4.91% of the total score, while the back has a score of 39, or 4.67%. The left and right wrists each scored 33, or 3.95%. The left and right hands each scored 32, or 3.83%, not 3.95%.

Table 7. Nordic Body Map score matrix and the percentage contribution of each body part for 13 operators

1	2	3	4	5	6	7	8	9	10	11	12	13	JUMLAH	%
2	3	2	2	4	4	3	2	1	2	2	2	2	31	3,71%

1	3	1	2	4	4	3	2	1	2	2	2	2	29	3,47%
2	4	2	2	2	3	4	1	2	2	2	2	2	30	3,59%
2	4	2	2	2	3	4	2	2	2	2	2	2	31	3,71%
1	4	2	2	4	4	4	2	1	2	2	3	2	33	3,95%
2	4	2	4	4	4	4	3	3	2	2	3	2	39	4,67%
1	4	2	2	4	4	4	2	1	2	2	3	2	33	3,95%
3	4	2	4	4	4	4	3	2	3	2	3	3	41	4,91%
2	2	1	2	3	2	3	2	1	1	1	1	2	23	2,75%
2	2	1	2	3	2	3	2	1	1	1	1	2	23	2,75%
2	2	2	2	2	3	4	2	1	1	1	1	2	25	2,99%
2	2	2	2	2	3	4	2	1	1	1	1	2	25	2,99%
2	3	3	2	2	4	3	1	2	2	2	2	2	30	3,59%
2	3	3	2	2	4	3	1	2	2	2	2	2	30	3,59%
2	4	2	3	2	4	4	2	2	2	2	2	2	33	3,95%
2	4	2	3	2	4	4	2	2	2	2	2	2	33	3,95%
2	3	2	3	3	4	3	2	2	2	2	2	2	32	3,83%
2	3	2	3	3	4	3	2	2	2	2	2	2	32	3,83%
2	3	2	2	3	3	3	2	1	2	2	2	2	29	3,47%
2	3	2	2	3	3	3	2	1	2	2	2	2	29	3,47%
2	3	2	2	3	3	4	2	2	2	2	2	3	32	3,83%
2	3	2	2	3	3	4	2	2	2	2	2	3	32	3,83%
2	3	1	2	2	2	3	2	1	2	2	1	2	25	2,99%
2	3	1	2	2	2	3	2	1	2	2	1	2	25	2,99%
2	3	2	2	2	2	3	2	1	2	2	2	2	27	3,23%
2	3	2	2	2	2	3	2	1	2	2	2	2	27	3,23%
2	3	2	2	2	3	4	1	1	2	2	2	2	28	3,35%
2	3	2	2	2	3	4	1	1	2	2	2	2	28	3,35%
54	88	53	64	76	90	98	53	41	53	52	54	59	835	

Based on Table 7, the results of the Nordic Body Map (NBM) questionnaire administered to 13 manual router operators showed a total Kor score of 835 across the 28 body parts measured. The body part with the highest score was the waist, at 41 (4.91%), followed by the back with a score of 39 (4.67%). Furthermore, the left and right upper arms, as well as the left and right forearms, each received a score of 33 (3.95%), while the left and right hands each received a score of 32 (3.83%). These results indicate that the waist and back are the body parts contributing the most to the Kor score. In the NBM method, each body part is assigned a score from 1 to 4, where a score of 1 means "no pain," a score of 2 means "some pain," a score of 3 means "pain," and a score of 4 means "severe pain." The higher the score, the more severe the complaints experienced by the workers. The total score from the 28 body parts was then used to determine each operator's Kor category: scores of 28–49 fall into the low category, 50–70 into the moderate category, 71–91 into the high category, and 92–112 into the very high category. The low category indicates relatively mild complaints; the moderate category indicates complaints that require attention; and the high category indicates more severe complaints that require the company's intervention.

Summary of NBM Results by Operator and Body Part

The NBM matrix yielded a total of 835 scores from 13 operators. Table 8 shows calculation score every respondents and their categories.

Table 8. NBM risk scores and categories for 13 operators

Respondents	NBM total score	Risk categories
Operator 1	54	Currently
Operator 2	88	Tall
Operator 3	53	Currently

Respondents	NBM total score	Risk categories
Operator 4	64	Currently
Operator 5	76	Tall
Operator 6	90	Tall
Operator 7	98	Very high
Operator 8	53	Currently
Operator 9	41	Low
Operator 10	53	Currently
Operator 11	52	Currently
Operator 12	54	Currently
Operator 13	59	Currently
Total of all respondents	**835**	13 operators

Based on Table 8, the results of the Nordic Body Map (NBM) assessment of 13 manual router operators showed a total Kor score of 835, with varying levels of complaints among the operators. Operator 7 received the highest score, 98, and fell into the "very high" category, indicating that this operator experienced the most severe Kor based on the NBM assessment and therefore requires primary attention. Furthermore, Operator 6 scored 90, Operator 2 scored 88, and Operator 5 scored 76; all of these fall into the "high" category and require company intervention. A total of eight operators (61.5%) were in the "moderate" category with scores ranging from 52 to 64, while Operator 9 had the lowest score 41 and fell into the "low" category. These results indicate that most operators experience moderate levels of discomfort, but there are four operators (30.8%) in the high and very high categories who require more serious attention. The differences in scores among operators suggest that the levels of discomfort experienced vary, even though they work in the same production section. However, the cause of these differences cannot yet be determined with certainty because data regarding work duration, movement frequency, and the individual conditions of each operator have not yet been analyzed. Therefore, the company needs to prioritize the assessment and improvement of working conditions, especially for operators with high and very high scores, to help reduce the risk of muscle and joint disorders.

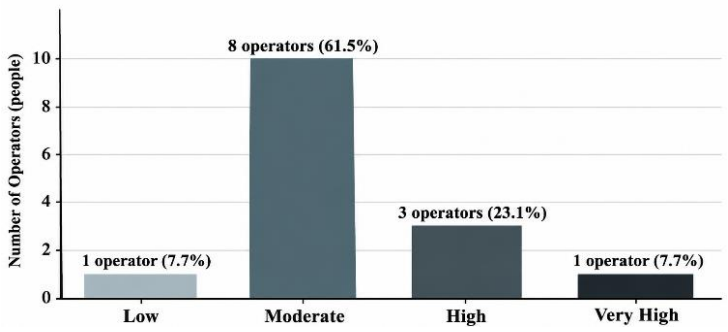


Figure 6. Distribution of the number and percentage of operators by NBM risk category

Based on the contribution of body part scores, the waist received the highest score, namely 41 out of 835 (4.91%), followed by the back with 39 (4.67%). The left and right upper arms and the left and right wrists each scored 33 (3.95%), while the left and right hands each scored 32 (3.83%). Details of the eight body parts with the highest relative scores are presented in Figure 7.

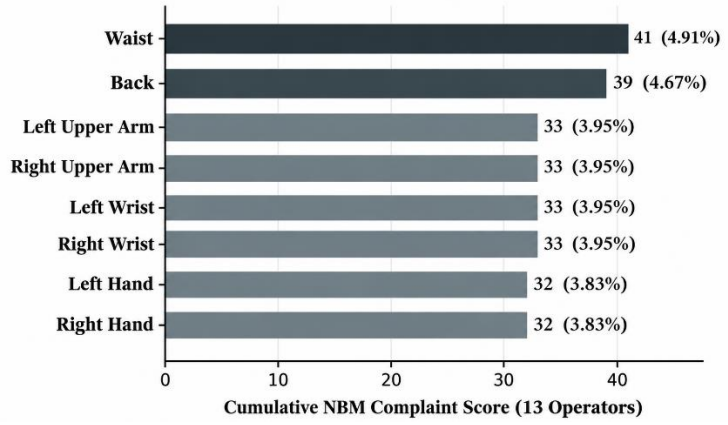


Figure 7. Eight body regions with the highest NBM complaint scores

Initial Recommendations for Ergonomic Improvements

Based on the NBM results and posture assessments, Table 9 presents alternative improvements that can be prioritized for further evaluation. These recommendations have not yet been implemented and are not accompanied by REBA scores following the improvements.

Table 9. Risk factors and initial recommendations for ergonomic improvement

Factor risks and findings	Design tool help or repair	Expected benefits	Indicator success
Stem body bent 65°. NBM score of waists 41 and back 39.	Table working router at a height can arranged in accordance operator needs.	Reduce position bending and strain on the back as well as waist.	Decline corner bending, REBA scores, and complaints waist.
Neck bows 28°.	Arrange height and position object Work as well as lighting of the cutting area.	Makes it easier for operators to see object Work without to bow down.	Decline angle and duration neck bow down.
Arm reach object work. NBM arm score on left and right 33 each.	Material mounts that can be shifted and locked.	Reduce range arms and help shoulder position more comfortable.	Decline distance arm REBA range and score on.
Potential materials shift moment processed.	Jig or material clamp with system lock quick (quick-release clamp).	Keeping the material constant stable so that second hand can control the router.	Improvement material stability and degradation shift moment cutting.
Wrist hand left and right own NBM score 33; hand left and right 32.	Rail guide or a compatible router guide with tool.	Help movement cutting more directed and reduce correct position hand.	Decline corner wrist hands and mistakes cutting.
Additional score +2 load and quality +2 grip not yet have supporting data.	Measure style Work as well as inspect heavy tools, conditions handle, and sharpness router eye.	Reduce need power overdo and fix comfort handle.	Measurement results style, condition handle, and REBA scores that have been verified .
Potential movement repetitive and static positions	Arrange Rest short and rotation work based on frequency as well as duration movement.	Give chance muscle rest and reduce exposure movement repeating.	Decreased static posture duration and score NBM complaints.
Activity stands during work	Evaluation use of standing base stable and non - fatigue slippery.	Increase foot comfort when the operator is standing in long time.	Decline leg complaints and improvement reported comfort.

DISCUSSION

The results of this study along with [1], which found that 58.68% of 167 wood furniture workers in Thailand experienced musculoskeletal disorders indicate that activities such as reaching, twisting the body, and lifting loads are associated with increased muscle fatigue. Similar findings were observed in the back and waist areas, which were the primary areas of concern. These results are also consistent with [2], which found that 88.33% of 60 wood-cutting workers were at an ergonomic setup level requiring immediate action. The study found a relationship between ergonomic setup and back pain and hand pain. Additionally, [3] reported that 39.5% of 656 garment workers experienced lower back pain in the past 12 months, and more than 53% of workers in the REBA assessment group were classified as high or very high risk. These similarities indicate that poor body posture is a significant

issue across various job tasks. However, this study has not yet established a causal relationship between the posture of manual router operators and the reported complaints.

Study [4] showed that the duration workers spend in a bent-over position is associated with increased lower back pain. That study used body motion tracking devices to record work positions over several days. These findings provide further evidence that ergonomic risk is influenced not only by the magnitude of body angles but also by the duration of that position. In the study's router operator guidelines, a recorded trunk angle of 65° indicates a suboptimal posture that requires evaluation. However, the duration of the bent-over position was not measured, so it remains unknown how long operators remained in that position during work. The results of study [5] also broaden our understanding by showing that an ergonomic improvement program for 181 vehicle assembly workers over the course of one year was followed by a significant reduction in ergonomic risks and muscle complaints. This study provides a basis for the idea that changes to workplace facilities and the use of assistive devices can be part of risk-reduction efforts. Furthermore, [6] explains that each ergonomic assessment method has different capabilities and limitations. Therefore, the use of REBA requires support from measurements of posture, load, grip, and activities that correspond to actual working conditions.

The results of this study do not fully align with [7], which found that 85% of garment workers fell into the low NBM complaint category and 15% into the moderate category, with no workers in the high category. In contrast, a study of manual router operators showed that a large proportion of operators fell into the moderate category; in fact, 30.8% of operators were in the high and very high categories. These differences may be related to the type of work, body position, duration of work, and varying workplace conditions. However, the exact causes of these differences cannot yet be determined from the available data. Different results were also found in [8], which reported that the relationship between work posture and musculoskeletal complaints among 30 rice mill workers was not statistically significant. These findings suggest that work posture is not the only factor to consider when assessing musculoskeletal health. Other factors, such as length of service, workload, physical condition, and rest periods, also need to be investigated. The study on manual router operators did not conduct a statistical test of the relationship between NBM scores and REBA scores; therefore, the results cannot be used to conclude that high REBA scores cause high NBM complaints.

RESEARCH CONTRIBUTIONS AND LIMITATIONS.

This study contributes by providing a breakdown of complaint levels across all 13 router operator manuals and a risk assessment of one documented work posture. These results can help companies identify operators requiring attention, prioritize body parts, and evaluate necessary workplace facilities. However, the study still has limitations because the sample size was only 13 respondents, the REBA assessment was conducted for only one posture, and comprehensive measurements regarding work duration, movement frequency, work load or force, and tool quality are not yet available. Additionally, no pre- and post-improvement testing has been conducted. Therefore, future research should evaluate more postures and operators, re-examine the REBA scores, and (text unclear) directly assess the use of ergonomic aids. A comparison of REBA scores, NBM complaints, and processing times before and after the improvements is necessary to determine whether the design can truly reduce occupational risks and assist operators in their work.

CONCLUSION

This study shows that the work of manual router operators at PT Delapan Intan Mutiara involves ergonomic risks that require attention. Based on the Nordic Body Map (NBM) assessment of 13 operators, eight operators (61.5%) fell into the moderate Kor category, three operators (23.1%) into the high category, one operator (7.7%) into the very high category, and one operator (7.7%) into the low category. Of the total 835 NBM scores, the body parts with the highest Kor contributions were the waist with a score of 41 (4.91%) and the back with a score of 39 (4.67%), followed by the upper arms and the left and right hands, which each scored 33 (3.95%). The Rapid Entire Body Assessment (REBA) evaluation of one work posture yielded an initial score of 13, which falls into the very high-risk category; therefore, this posture requires immediate evaluation. However, this score still needs to be reconfirmed because several assessment components such as workload, grip quality, and activity—have not yet been fully measured. Based on these findings, the recommended ergonomic improvements include the use of a height-adjustable workbench, material clamps, and a router motor drive to help reduce travel distance, excessive hand reach, and difficulty holding tools. This study provides valuable information on the body parts requiring attention and serves as a basis for companies to determine workplace facility improvements. However, the success of the proposed improvements cannot yet be confirmed because direct testing has not been conducted. Therefore, future research should measure REBA scores and NBM complaints both before and after the improvements to determine whether the redesigned workplace facilities can effectively reduce ergonomic risks.

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CONFLICT OF INTEREST
The authors declare that there are no conflicts of interest related to this research, its findings, or the publication of this article.

DATA AVAILABILITY STATEMENT
The data used in this study were collected through Nordic Body Map (NBM) questionnaires, workplace observations, and postural assessments. Supporting data may be obtained from the corresponding author upon reasonable request, subject to participant confidentiality and company approval.

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DECLARATION OF AI TOOL USAGE
No artificial intelligence (AI)

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