# Improvement Of Work Posture In Yarn Removal Operator To Reduce Risk Of Musculoskeletal Disorders

**Bambang Suhardi, Karima Batennia M, Rahmaniyah D A**

**Abstract:** The highest number of industrial workers who experience Musculoskeletal Disorders is in the garment industry, which is equal to 65.2%. PT. Panen Mas Jogja is a company engaged in the garment sector. PT. Panen Mas Jogja has a production target per day of 720 products for each line. But actually, the average of product that cannot be achieved is 34.32%. Based on the assessment of work posture using REBA method, it is known that 71% of the work elements need improvement, 19% of the work elements may need improvement and 10% of the elements need to be improved immediately. The work element that has the highest risk of posture is then assessed using the NBM questionnaire. Based on the assessment, the work element of taking the product and putting the product in the yarn removal activity have the highest final score of 72. Because these work elements have the same work station, improvement will be made for the yarn removal activity.

**Index Terms**: Musculoskeletal Disorders, NBM, REBA, Work Posture

## 1 INTRODUCTION

Musculoskeletal Disorders (MSDs) is the complaints on the skeletal muscle that felt by someone from mild to very painful [1]. Because of this, one-third of working time will be lost or commonly known as lost injuries times [2]. Unnatural posture, excessive muscle movements, repetitive activity and length of working time are factors that can increase the occurrence of MSDs [3]. Problem related to body posture and repetitive work is one of the problems of ergonomics in the garment industry. This has the potency to cause Cumulative Trauma Disorder and Repetitive Strain Injuries (RSI) [4]. The highest number of industrial workers who experience MSDs complaints in the garment industry is 65,2% [5]. One factor that influences work concentration is the level of MSDs which experienced by someone. This will cause fatigue and then will reduce a person's productivity [6]. Previous studies related to work postures and MSDs have been conducted by several researchers. Several studies aimed at analyzing the risk of work postures in the micro, small and medium scale industries in several countries have been carried out [7,8,9,10,11,12,13,14]. The work posture risk analysis uses various methods such as Rapid Upper Limb Assessment (RULA), Quick Exposure Checklist (QEC), Nordic Body Map (NBM), Ovako Work Posture Analysis (OWAS), and Rapid Entire Body Assessment (REBA). A study to compare between the result of using RULA and the result of using REBA has also been done before [15]. That study was conducted to see how similar or different them in assessing the risk involved in the same working condition. In addition to using these tools to assess the risk of work posture, a study has also developed a new approach called Working Posture Controller (WPC) [16]. The WPC automatically monitors and assesses posture when a worker is doing his job. In addition to assessing work posture, several studies have also been carried out to improve work posture by designing and modifying work facilities [17,18,19,20]. Research to investigate the effect of work stations on job satisfaction has also been conducted [21]. That study involved librarians who worked at several universities in Southern Nigeria. PT. Panen Mas Jogja (PMJ) is a company engaged in the field of garment with the production of women's underwear. Underwear production process through three departments, namely the department of cutting, sewing, and packing. PT. PMJ has a production target of 720 products per day for each line. However, the production target set by management was not achieved. The average non-achievement of the production target is 34,32%. Based on observation, not achieving production target is caused by unnatural work postures in the process of producing underwear.

One example of unnatural work posture occurs in the cutting department. Production process activities in the cutting department are carried out with unnatural work postures that can lead to MSDs. Based on inteviews with operators in the cutting department, they complained about aches and pains in several parts of the body, namely arms, waist, and legs. Production process activites in the cutting department include spreading, cutting, bundling, molding, and joining. Operators carry out the process of spreading, molding and joining with a standing work posture continuously during working hours. Operators carry out the process of cutting the fabric according to the pattern with a standing work posture and bending the body towards the band knife for a long time. Operators carry out the bundling process with a standing posture then squat down when they combine the result of the fabric ties. That work postures can be called as unnatural work postures. As a consequence of unnatural work postures on workers at PT. PMJ, then the time needed to complete the work become longer and workers are also more at risk of experiencing work accidents or damage to property [22] Workplace is an aspect that greatly influences one's performance. The workplace environment puts a lot of physical pressure on workers [23]. Workplace must be ergonomically designed so that workers can carry out their work safely and effectively [24]. Things that must be considered in designing workplace include tasks performed, use of tools, user specifications and work environment [25]. In addition, there are several other criteria in developing an ergonomic workplace such as range,

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anthropometry, muscle ability and visual ability [24]. One of the principles of ergonomics that should be applied to workplace design is to avoid unnatural work postures such as bending [26]. Handling the risk of unnatural posture can be done by designing equipment and work methods used, so that posture during work become more comfortable [27]. Because humans cannot be redesigned, machines and other production equipment must be well designed so that workers can use them easily [28]. For this reason, it is necessary to assess the risk of work posture in the women's underwear production. Work posture risk assessment is used as a basis for improving work facilities in the women's underwear production department. The assessment of the operator's work posture risk in this study uses the REBA method. This method aims to assess the risk caused by body posture [29]. The REBA method only evaluates aspects of the operator's work posture without regard to the severity level or complaints experienced by the operator. To assess the severity of the disruption or injury to musculoskeletal system, the NBM method is used. This method is an advanced assessment method of the REBA method [30]. The novelty of this study is the use of the REBA method to assess the risk of work posture first, then use the NBM method to assess the severity or complaints experienced by operators. Another novelty of this study is the use of NIDA method (Need, Idea, Decision, Action) to design work facilities.

## 2 Methodology

The object of this study is operators in the cutting department, sewing department, and packing department. The data required includes: operator work posture documentation in three departments, operator complaints related to MSDs obtained using the NBM questionnaire, operator work time for each work element, and operator anthropometry data. Documentation of the operator's work posture becomes an input to assess the risk of work posture using the REBA method. The operator's work posture with the highest value resulting from the REBA method will be an input for assessing the severity or complaints experienced by the operator. Assessment of severity or complaints experienced by operators uses the NBM questionnaire. The stages in this study were divided into five stages. The first stage is the assessment of the production operator's work posture risk using the REBA method. The second stage is the assessment of the severity level or operator complaints using the NBM questionnaire. Work posture that will be assessed using NBM questionnaire is work posture that has the highest risk value for work posture. The third stage is the selection of production process activity that will be improved. Determination of selected activity is based on the highest NBM value. It also must consider the operator's time duration in completing their work. The fourth stage is the design of the proposed work facility design. The design of the proposed work facility uses the NIDA concept. In the Need stage, identification of operator requirements related to the work facilities that will be created will be carried out. In the Idea stage, researchers determine several alternative solutions to meet user needs. In the Decision stage, an assessment and analysis of alternatives that have been made is done so the researchers can determine which alternative decision will be designed. In the Action stage, work facilities are made in the form of design or protoytpe [31]. At this design stage, operator anthropometric data processing is also performed which includes the calculation of data adequacy, data normality and percentile. Percentile calculation is used to determine the dimension of the work facility that will be made. The fifth stage is the design of the work facility.

## 3 Result and Discussion

The assessment of the work posture of the operator when doing work is done using the REBA method. The higher the REBA value, the more likely the occurrence of MSDs both in the short and long term. In the assessment of work posture risk for operators in three departments, the results obtained are 68,6% work element need improvement (35 work elements), 21,6% work elements may need improvement (11 work elements), and 9,8% work elements need immediate improvement (5 working elements). A complete work posture risk assessment is shown in Table 1.

***TABLE 1***

*Results Of Assessment Using The Reba Method*

| Dept | Activity | Work Element | REBA Score | Risk Level |
|---|---|---|---|---|
| Cutting | Spreading | Reach the fabric roll | 6 | Need Improvement |
| | | Lift fabric roll to the table | 7 | Need Improvement |
| | | Put fabric roll on the table | 4 | Need Improvement |
| | | Reach iron | 2 | May Need Improvement |
| | | Install the iron | 2 | May Need Improvement |
| | | Reach the iron to install on fabric roll | 2 | May Need Improvement |
| | | Lift fabric roll to the pole with iron | 6 | Need Improvement |
| | | Put fabric roll on a pole | 4 | Need Improvement |
| | | Unrolling the fabric | 7 | Need Improvement |
| | | Roll out the fabric | 4 | Need Improvement |
| | | Move the fabric | 4 | Need Improvement |
| | Cutting | Clamp the fabric | 2 | May Need Improvement |
| | | Fold the fabric | 3 | May Need Improvement |
| | | Move the fabric to the cutting table | 2 | May Need Improvement |
| | | Reach the fold of fabric | 5 | Need Improvement |
| | | Direct the fabric | 4 | Need Improvement |
| | | Cut the fabric | 6 | Need Improvement |
| | | Put a piece of fabric | 3 | May Need Improvement |

TABLE 2

Results of Assessment Using The REBA Method (Cont.)

| Dept | Activity | Work Element | REBA Score | Risk Level |
|---|---|---|---|---|
| Cutting | Bundling | Reach the pieces of fabric | 5 | Need Improvement |
| | | Tie the fabric | 5 | Need Improvement |
| | | Put the fabric in the bag | 7 | Need Improvement |
| | Molding | Reach the fabric | 4 | Need Improvement |
| | | Direct the fabric to the molding machine | 5 | Need Improvement |
| | | Take fabric to a molding machine | 4 | Need Improvement |
| | | Put the fabric | 4 | Need Improvement |
| | Joining | Take the pieces of fabric from the cardboard | 4 | Need Improvement |
| | | Take out a piece of fabric | 3 | May Need Improvement |
| | | Reach the pieces of fabric | 2 | May Need Improvement |
| | | Combine pieces of fabric | 5 | Need Improvement |
| Sewing | Solder | Take the fabric | 5 | Need Improvement |
| | | Fold the fabric | 6 | Need Improvement |
| | | Reach the solder | 4 | Need Improvement |
| | | Soldering | 6 | Need Improvement |
| | Sewing | Take the fabric | 8 | Immediate Improvement |
| | | Put the fabric on the table | 4 | Need Improvement |
| | | Direct the fabric to the sewing machine | 4 | Need Improvement |
| | | Sewing | 5 | Need Improvement |
| | | Cut the stitches | 5 | Need Improvement |
| | Yarn Removal | Take the product | 8 | Immediate Improvement |
| | | Remove the yarn | 5 | Need Improvement |
| | | Put the product | 8 | Immediate Improvement |
| | Inspection | Reach the product | 6 | Need Improvement |
| | | Check product quality | 8 | Immediate Improvement |
| | | Put the product on the table | 5 | Need Improvement |
| | | Put the product in the bag | 4 | Need Improvement |
| | | Put the bag on the crate | 3 | May Need Improvement |
| Packing | Product Packing | Take the product from the cardboard | 4 | Need Improvement |
| | | Put the product on the table | 3 | May Need Improvement |
| | | Install a hang tag | 6 | Need Improvement |
| | | Put the product in a poly bag | 5 | Need Improvement |
| | | Insert the product into a cardboard | 4 | Need Improvement |
| | | Move the cardboard | 8 | Immediate Improvement |

Based on Table 1, there are 5 working elements with a value of 8 which means that they must be improved immediately. The work elements with the highest value are in the sewing department and packing department. Operators who have the highest work value element will be assessed using the NBM questionnaire. In addition, the duration of time required by the operator to complete the work element is also measured. The result of the NBM assessment questionnaire is shown in Table 2.

***TABLE 2***

*NBM Assessment Questionnaire*

| No | Skeletal Muscle | Operator Complaint on Each Activity | | | |
|---|---|---|---|---|---|
| | | Sewing | Yarn Removal | Inspection | Packing |
| 0 | Upper neck | 1 | 2 | 2 | 2 |
| 1 | Nape | 2 | 2 | 3 | 2 |
| 2 | Left shoulder | 4 | 2 | 2 | 1 |
| 3 | Right shoulder | 4 | 2 | 2 | 1 |
| 4 | Left upper arm | 1 | 2 | 1 | 2 |
| 5 | Back | 4 | 2 | 3 | 2 |
| 6 | Right upper arm | 2 | 2 | 3 | 2 |
| 7 | Waist | 4 | 3 | 2 | 2 |
| 8 | Hip | 4 | 3 | 2 | 3 |
| 9 | Buttocks | 3 | 1 | 2 | 1 |
| 10 | Left elbow | 1 | 2 | 2 | 1 |
| 11 | Right elbow | 2 | 3 | 1 | 1 |
| 12 | Left forearm | 1 | 3 | 1 | 2 |
| 13 | Right forearm | 2 | 2 | 3 | 1 |
| 14 | Left hand wrist | 1 | 2 | 1 | 2 |
| 15 | Right hand wrist | 2 | 2 | 3 | 2 |
| 16 | Left hand | 1 | 3 | 1 | 2 |

The recapitulation of the result of the NBM questionnaire assessment and the duration of time for each element of work are shown in Table 3.

***TABLE 3***

***Result of the NBM Method Assessment and Time Duration***

| Departement | Activity | No | Work Element | NBM | Time (s) |
|---|---|---|---|---|---|
| Sewing | Sewing | 1 | Take the fabric | 61 | 19,61 |
| | Yarn Removal | 1 | Take the product | 72 | 110,7 |
| | | 2 | Put the product | | 108 |
| | Inspection | 1 | Check product quaility | 53 | 2320,2 |
| Packing | Product Packing | 1 | Move the cardboard | 60 | 51,55 |

Yarn removal activity in the sewing department was selected for improvement. This is based on the highest NBM value of 72. A value of 72 is categorized as a high level of risk or can be said that action is needed immediately [30]. This is also supported by the duration of time the operator performs the work element. Yarn removal activity consists of two working elements, namely taking the product with a time of 110,7 seconds and placing the product with a time of 108 seconds. Although the product packing activity in the packing department has a longer duration of time, which is 2.320,2 seconds, but the NBM value is only 53. Value of 53 is categorized as low risk or it can be said that action may be needed in the future [30]. This reason causes the product packing activity not to be selected for improvement. Work posture of yarn removal activity is shown in Figure 1.

The operator of yarn removal, in the initial condition, doing her work by standing for 7 hours of work. The operator stands with one foot support and change her footstool occasionally. The operator occasionally bends down to pick up the product that will be yarn removed. The result of the NBM assessment for yarn removal activity produce a value of 72. Operators in the yarn removal activity experience discomfort in parts of the body as shown in Table 2. The results of this study reinforce previous studies which state that unnatural work postures such as standing continously for long periods of time can cause musculoskeletal complaints and disorders of the spine [32,33,34]. Complaints in the leg can reduce the ability to move, efficiency, and muscular endurance. So that, it will affect work productivity. To improve the work posture of the yarn removal operator, a work facility design is performed using the NIDA method. The first stage of the design is identification of the complaints and the needs of the operators as shown in Table 4. Identification of the complaints and the needs was obtained through interviews with 29 yarn removal operators.

***TABLE 4***

*Worker Complaints and Worker Needs for Yarn Removal Activity (Need)*

| Worker Complaints | Descriptions of Needs |
|---|---|
| Operators feel uncomfortable because they doing their work in a standing position for a very long period of time. Thus, operators often stand on one foot support and then in some time change their footstool. | - There is work facility in the form of comfortable and ergonomic chair to reduce pain and discomfort felt by the operators. |
| Operators feel pain in the right and left calf, right and left thigh, and right and left ankle. | - There is work facility in the form of chair that has a stretcher to support the feet.<br>- There is ergonomic footrest on the table to rest the foot. |

The next stage after obtaining the description of the needs of the yarn removal operators is the elaboration of alternative solutions or called as alternative variables to create the work facility that is designed. The following are work facility design solutions to meet operator needs:

1. Design a chair that has a seat cushion so that workers feel comfortable when sitting for long periods of time. Chair is used for sitting work posture and occasionally standing to reduce MSDs complaints based on operators anthropometric data.

2. Add a stretcher feature on chair and footrest on table that will be designed to support the foot.

After obtaining alternative solutions from the needs, the next step is to create a classification tree and combination table to organize problem solving thinking. The classification tree is used to consider several combination concepts or alternative solutions of product design [35]. Classification tree and combination table are shown in Figure 2 and Table 5

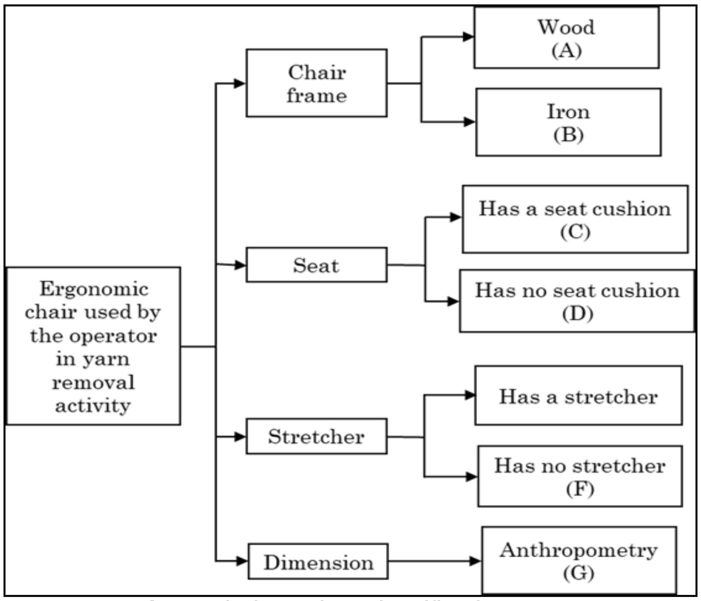


***Fig. 2*** *Chair Design Classification Tree*

***TABLE 5***

*Combination Table of Alternative Chair Design*

| Altrnative | Combination |
|---|---|
| Alternative 1 | ACEG |
| Alternative 2 | ADEG |
| Alternative 3 | ACFG |
| Alternative 4 | ADFG |
| Alternative 5 | BCEG |
| Alternative 6 | BDEG |
| Alternative 7 | BCFG |
| Alternative 8 | BDFG |

Based on combination of design alternative that has been obtained, then the product concept is chosen. This product concept selection uses a matrix to evaluate each concept by considering a series of selection criteria. The concept selection matrix can be seen in Table 6.

***TABLE 6***

*Concept Selection Matrix*

| Criteria | Alternative | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Convenience | + | - | - | - | + | - | - | - |
| Durability | + | + | + | + | - | - | - | - |
| Price | - | - | - | - | + | + | + | + |
| Ease of manufacture | - | - | - | - | + | + | + | + |
| Amount + | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 2 |
| Amount - | 2 | 3 | 3 | 3 | 1 | 2 | 2 | 2 |
| Final score | 2 | 3 | 2 | 3 | 1 | 2 | 2 | 2 |
| Continue? | No | No | No | No | Yes | No | No | No |

From the decision matrix table above, it can be concluded that the chair with alternative 5 is a chair design chosen by the company's stakeholders to improve the posture of the yarn removal operators when doing their work.

The next step is the collection of anthropometric data that will be used for the design and processing anthropometric data which includes data adequacy test, data normality test, uniformity test, and percentile calculation which is used to determine the size of work facilities. The population of this design is the operator at PT. PMJ and the sample in this design are operators of yarn removal activity which has 29 people. The body dimensions used in the design of the proposed facility are hip width, standing buttock height and popliteal length. The width of the hip is used to determine the width of the seat, the height of the buttock while standing is used to determine the height of the chair that is designed for a sit-stand position, and the popliteal length is used to determine the length of the seat. The anthropometric dimensions of the operators can be sen in Table 7.

***TABLE 7***

*Operator Anthropometry Dimensions*

| Name | Dimension (cm) | | |
|---|---|---|---|
| | Hip Width | Standing Buttock Height | Popliteal Length |
| Operator 1 | 30 | 76 | 41 |
| Operator 2 | 31 | 78 | 40 |
| Operator 3 | 24 | 71 | 41 |
| Operator 4 | 31 | 74,5 | 45 |
| Operator 5 | 29 | 72,5 | 46 |
| Operator 6 | 30 | 72 | 43 |
| Operator 7 | 29,5 | 70 | 39 |
| Operator 8 | 25,5 | 71 | 44,5 |
| Operator 9 | 32,5 | 77 | 44 |
| Operator 10 | 32 | 74 | 39,5 |
| Operator 11 | 29 | 72 | 42,5 |
| Operator 12 | 26 | 74 | 44 |
| Operator 13 | 28 | 74,5 | 46 |
| Operator 14 | 29 | 76 | 47 |
| Operator 15 | 27 | 72 | 45 |
| Operator 16 | 29 | 74 | 43 |
| Operator 17 | 29 | 73 | 48 |
| Operator 18 | 33 | 72 | 41 |
| Operator 19 | 31 | 71 | 41 |
| Operator 20 | 29 | 75,5 | 47 |

***TABLE 7***

*Operator Anthropometry Dimensions*

| Name | Dimension (cm) | | |
|---|---|---|---|
| | Hip Width | Standing Buttock Height | Popliteal Length |
| Operator 21 | 33 | 75 | 43 |
| Operator 22 | 32,5 | 76 | 46 |
| Operator 23 | 34 | 77 | 47 |
| Operator 24 | 27 | 73,5 | 41 |
| Operator 25 | 32 | 74 | 45 |
| Operator 26 | 34 | 74 | 42 |
| Operator 27 | 32 | 77 | 44 |
| Operator 28 | 33 | 79 | 46 |
| Operator 29 | 33,5 | 74 | 41 |

The next step is data adequacy test, normality test, and uniformity test . The results of data adequacy test, normality test, and uniformity test are respectively shown in Table 8.

***TABLE 8***

***The results of Data Adequacy Test, Normality Test and Anthropometric Data Uniformity Test***

| Dimension | Data Adequacy | Data Normality | Data Uniformity |
|---|---|---|---|
| Hip Width | Adequate | Normal | Uniform |
| Standing Buttock Height | Adequate | Normal | Uniform |
| Popliteal Length | Adequate | Normal | Uniform |

The next step is the calculation of percentile which will be used to determine the dimension of the facility that will be designed. The percentile that will be used for the dimensions of hip width, standing buttock height, and popliteal length is the 95th percentile. After the percentile value for each dimension is obtained, the next step is determining the size of the chair for sit-stand posture. The dimension of the designed chair can be seen in Table 9.

***TABLE 9 Chair** Dimension*

| Design Dimension | Anthropometric Dimension | Percentile | Design Size (cm) |
|---|---|---|---|
| Chair Height | Standing buttock height | P-95 | 78 |
| Seat Width | Hip width | P-95 | 35 |
| Seat Length | Popliteal length | P-95 | 48 |

The following is the stage for making chair design in the form of 2D and 3D images. This design was created using SolidWorks software. The design of the chair can be seen in Figure 3 and Figure 4.

***Fig. 3 Chair** Design Result in 3D*

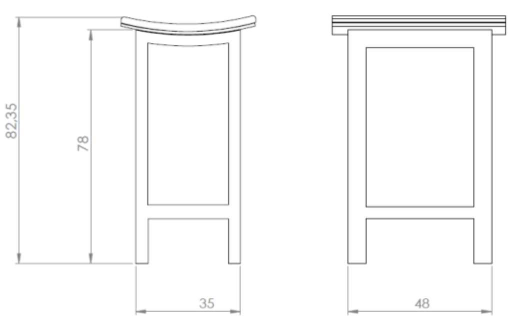


***Fig. 4** Chair Design Result in 2D*

The table used by the operator when removing yarn already exists. But there is a feature that is expected by the operator but not yet there. This feature is a footrest that aims to rest the operator's feet when sitting. The footrest has a slope, so that the operator become more comfortable. The slope of the footrest was made at 15° as suggested by previous researcher [30]. The design of the proposed table can be seen in Figure 5 and Figure 6.

***Fig. 5** Proposed Table Design in 3D*

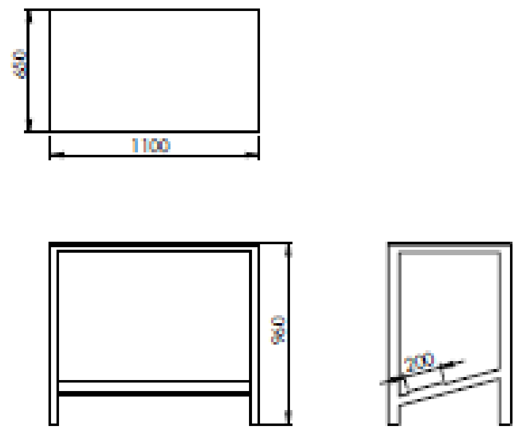


***Fig. 6** Proposed Table Design in 2D*

## 4 Conclusion

Identification of work posture risk to the operator of the production department at PT. PMJ using the REBA method shows that all elements of work still have risks and need improvement. Work elements that have the highest risk of posture are then assessed using the NBM questionnaire. Based on the assessment, the work element "take the product" and "put the product" in yarn removal activity have the highest final score, so those work elements must be improved. The design of work facility is based on the NIDA method which aims to reduce the risk of MSDs in the form of chair for sit-stand work posture and modification of table feature on footrest.

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