



Design of an Ergonomic Prototype for Oil Palm Harvesting and Post-Harvesting Aid to Reduce the Risk of Musculoskeletal Disorders

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Abstract.

Background. Oil palm harvesting has many steps until the oil palm fruit can be distributed to the next stage. It began with cutting oil palm fronds using egrek aids, picking up oil palm with a corner tool, and transporting it with angkong aids.

Aims. Blind prototype of egrek, tojok, and angkong aids in reducing cases of *Musculoskeletal Disorders* (MSDs) that occur in workers.

Method. The measurement method of MSDs with the *Nordic Body Map* and *Rapid Entire Body Assessment* (REBA). Prototype design with literature study and prototyping practices.

Result. Modified Egrek tools, designed by the researcher, can make it easier for harvesters to cut palm fronds. The results of this tool repair are able to reduce the REBA value. The corner aid enables the operator to avoid making sudden movements to withstand the mass load of fresh fruit bunches (FFB), thereby reducing the risk of MSDs interference. Ankle aids reduce the risk of injury to the wrist because they push heavy loads.

Conclusion. Prototypes of egrek, tojok, and angkong aids have succeeded in reducing the risk of MSDs in oil palm harvesting.

Keywords: MSDs; egrek; tojok; angkong; prototype



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INTRODUCTION

The oil palm harvesting process begins with cutting palm fronds, which must be removed to access the fruit. The process of taking fresh palm fruit bunches (FFB) to processing them at the factory requires good handling to achieve the expected Crude Palm Oil (CPO) yield (Manalu et al., 2020; Ningsih et al., 2021; Rambe et al., 2022). Next, the process of taking palm

fruits from trees, and finally, the process of transporting oil palm that has fallen to the ground. This research focuses on the process of cutting oil palm fronds and oil palm bunches using harvesting aids in the form of **egrek**. Egrek is a very sharp, curved knife shaped like a sickle, or celurite, but is used explicitly for harvesting oil palms.

In the palm oil production process, palm fruit, in the form of fresh fruit bunches, is processed to produce Crude Palm Oil (CPO). Initially, the ripe oil palm fruit bunches fall from the trees, which are then picked up by plantation operators and sent to palm oil processing plants. In the process of taking oil palm fruit bunches, the operator had to do it manually with limited facilities. The operator must perform a bowed body and neck-down movement to retrieve the FFB using a spear-type aid, referred to as a **Tojok**. **Tojok** is also used to move FFB from temporary containers to conveyors (trucks) to be taken to palm oil processing plants (Anizar 2015). Physical movement in this process can cause discomfort, because it is done repeatedly every day, as well as without adequate body relaxation time. Physical movements carried out by oil palm plantation operators can trigger the risk of MSDs. These health disorders involve muscles, tendons, ligaments, cartilage, the nervous system, bones, and blood vessels (Krishnan et al., 2021), as human muscles are forced to work continuously without adequate time for muscle and bone relaxation.

The next stage is transportation. Manual means of transportation, commonly called *angkong*, is a type of transportation that has one wheel at the front and is equipped with a container or body. **Angkong** is designed to transport a large amount of goods and is commonly used for agricultural products, construction materials, and other goods with large loads. Angkong is primarily used in the agricultural, construction, and industrial sectors to facilitate the transportation of goods. In harvesting oil palm *angkong*, it is necessary to transport fresh fruit bunches (FFB) that have been picked from oil palm trees in large quantities. Based on the results of the research, workers need more energy to push the *angkong*, therefore if it exceeds the limitations of human power, it can pose a risk of injury or pain from the worker's body parts which can cause *Musculoskeletal Disorders* problems (Monasari, 2006; Devi et al., 2017). MSDs are medical conditions caused by work-related factors, resulting from a mismatch between job demands and individual performance abilities within the work environment (Halim et al., 2012; Grandjean, 1998).

This study focuses on designing more efficient modifications of *egre*, *tojok*, and *angkong* aids to assist palm oil production without increasing the risk of MSDs interference in operators. In this study, we used interview methods, the *Nordic Body Map*, and REBA. Nordic

Body Map (NBM) is a subjective measurement method used to identify and measure complaints or pain in muscles and other body areas experienced by workers (Atmojo, 2020; Azwar, 2020; Krismanto, 2022). REBA is an accurate tool in measuring ergonomic working positions (Gorde et al., 2019; Ghasemi et al., 2020; Kusuma et al., 2020; Wibowo et al., 2021; Mithunraj et al., 2022). Thus, it is hoped that there is potential for the development of design and implementation to produce egrek, tojok, and angkong auxiliaries with modifications and novelties that reduce the risk of MSDs for operators, while supporting an increase in the effectiveness and productivity of the oil palm loading process in the Indonesian plantation sector.

LITERATURE REVIEW

Egrek Oil Palm Harvesting Aids

Nowadays, the tools and systems used for harvesting and loading palm oil are generally manual, with farmers using dodos and egrek tools for harvesting, as well as carts or angkongs for loading transportation. Several types of tools and technologies have been widely introduced and are in use today. For some conditions, these tools/technologies are pretty practical, but for others, they are less effective or less economical to apply. Manual harvesting activities also have the potential to cause occupational safety and health (K3) problems. Therefore, manual harvesting activities, especially egrek, need to be studied further so that the incidence of occupational health problems can be known. MSDs (Prabawati, & Lidiana, 2021).

The harvesting process uses tools in the form of an egrek. The extender used by the workers can be lengthened (8 meters) and shortened (4 meters), with a weight of 3 kg, made of lightweight aluminum with pipe connections. The use of this tool requires a large amount of muscle power from the worker. Cutting FFB is performed through repetitive hand movements, specifically pulling movements with the egrek. As a result, the attitude of oil palm harvest workers is unnatural, leading to physical problems such as musculoskeletal disorders (MSDs). The attitude of standing with an extension position on the neck for 1-2 minutes for 1 oil palm tree (5-7 meters high) which amounts to ± 120 trees and takes ± 4 hours of work which is quite long and monotonous, causes excessive use of muscles, tendons and neck joints and increases pressure on the nerves. A working position with the arms extended upwards, which causes the shoulders to be raised, resulting in inflammation in the joints (Damantal et al, 2018).

Oil palm harvesting work such as cutting fronds has a high risk that is harmful to health because it can cause MSDs in workers. MSDs are a disease that encompasses more than

150 different conditions that can affect joints, muscles, bones, ligaments, tendons, and the spine (Gill et al., 2023; Akbar et al., 2023; Andreson et al., 2016). Risk factors for MSDs in oil palm harvesting workers can be caused by repetitive movements, such as pulling, and also by ergonomically poor posture, as well as the length of time spent harvesting oil palm. The purpose of this study was to determine the profile of oil palm harvesters using egrek and the incidence rate of musculoskeletal disorders (MSDs) among these workers.

Angkong Oil Palm Harvesting Tools

Manual means of transportation, commonly called angkong, is a type of transportation that has one wheel at the front and is equipped with a container or body. Angkong functions to transport a large amount of goods and is commonly used for agricultural products, construction materials and other goods that have large loads. Angkong is used mainly in the agricultural, construction, and industrial sectors to make it easier to transport goods. In harvesting palm oil, angkong is needed to transport oil palm fresh fruit bunches (FFB) that have been harvested from oil palm trees in large quantities. Based on the results of the research, workers need more energy to push the angkong, therefore if it exceeds the limitations of human power, it can pose a risk of injury or pain from the worker's body parts which can cause *Musculoskeletal Disorders* problems (Monasari, 2006; Devi et al., 2017). MSDs are medical conditions caused by work-related factors, resulting from a mismatch between job demands and individual performance abilities within the work environment (Halim et al., 2012; Grandjean, 1998). In 2015, MSDs disorders accounted for 31% of the total worker injury cases, which were 356,910 cases (US Department of Labor, 2015). Disturbances that occur, such as sprains or strains, are often caused by fatigue during the lifting of goods. In 2015, musculoskeletal disorders (MSDs) accounted for 31% of the total worker injury cases, which were 356,910 cases (US Department of Labor, 2015). Disturbances that occur, such as sprains or strains, are often caused by fatigue during the lifting of goods. With the large number of cases of workers affected by MSDs, better handling is needed so that workers can obtain the right to work safely. In line with this, Law No. 1 of 1970 regulates occupational safety, stating that every worker has the right to protection for safety while performing work to ensure the welfare of life and increase national production and productivity. Research on the posture of workers when operating angkongs was conducted to improve the health of the workers' bodies and minimize the occurrence of MSDs complaints. The results of the study will later be proposed improvements to oil palm angkong tools (Hignett

et al., 2000; Scott, 2020; Wijaya, 2019; Haryudiniarti et al., 2022; Indonesian Anthropometry, 2013).

Research on the posture of workers when operating angkongs was conducted to improve the health of the workers' bodies and minimize the occurrence of MSDs complaints. The results of the study will later be proposed improvements to oil palm angkong tools (Hignett et al., 2000; Scott, 2020; Wijaya, 2019; Haryudiniarti et al., 2022; Indonesian Anthropometry, 2013).

Tojok Oil Palm Harvesting Aids

In the palm oil production process, oil palm fruits in the form of fresh fruit bunches are processed to produce Crude Palm Oil. Initially, the ripe oil palm fruit bunches fall from the trees, which are then picked up by plantation operators and sent to palm oil processing plants. In the process of taking oil palm fruit bunches, the operator had to do it manually with limited facilities. The operator must perform a bowed body and neck down movement to retrieve the FFB using a spear-type aid, called a Tojok. Physical movement in this process can cause discomfort because it is performed repeatedly every day, without adequate time for body relaxation. Physical movements carried out by oil palm plantation operators can trigger the risk of MSDs. These health disorders involve muscles, tendons, ligaments, cartilage, the nervous system, bones, and blood vessels (Krishnan et al., 2021), as human muscles are forced to work continuously without adequate time for muscle and bone relaxation.

This research focuses on designing more efficient modifications of the corner aids to assist palm oil production without increasing the risk of MSDs interference to operators. In this study, we used interview methods, the *Nordic Body Map*, and REBA. Thus, it is hoped that there is potential for the development of a design and implementation that can produce a corner aid with modifications and novelty, reducing the risk of MSDs for operators while supporting an increase in the effectiveness and productivity of the palm oil loading process in the Indonesian plantation sector.

MSDs

MSDs is a disease that cannot be underestimated. Farmers affected by the disease due to poor posture need to improve their posture by utilizing tools that maximize efficiency during harvesting, so that their posture is better when performing oil palm harvesting work. Oil palm smallholders are a vital component of the oil palm sector, as the absence of farmers would

render the oil palm business chain ineffective. Farmers who experience muscle pain or low back pain are one of the factors caused by unergonomic harvesting aids, resulting in MSDs (Anderson et al., 2016; Tamala et al., 2022; Kok et al., 2019; Sultan et al., 2022; Lina et al., 2023).

MSDs caused by unergonomic oil palm harvesting aids will be known by conducting field observations when oil palm farmers want to harvest using egrek aids. The observation process will be carried out on one of the oil palm plantations located in Sukabumi, serving as an example for the research. This will enable the development of more ergonomic modification tools, specifically by adjusting the height of the oil palm trees to better suit the needs of farmers.

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METHOD

To create prototypes of egrek, angkong, and tojok, observations were conducted at the Oil Palm Plantation of X Sukabumi Plantation for three months.

Prototype Oil palm harvesting aid (Egrek)

1. Identify MSDs problems experienced by Farmers;
2. Ergonomic data processing in the form of NBM value results from the average that has been obtained and analyzing the risk of injury from posture using REBA and the Nordic Body Map;
3. Egrek images are also carried out to find out the tools currently used by the company and performance analysis before and after the use of the proposed tools;
4. The design of the aids starts from identifying the needs of the user, followed by a literature study to find relevant reference to the design of the aids and carry out conceptual design and make a prototype using the help of the solidworks application and ends with a simulation posture analysis of the design of the aids that have been made.

Fresh Ketandan fruit transport equipment (Angklong)

1. Identification of MSDs: A potential risk of injury on the job that involves repetitive movements of the human body. This study utilizes full-body and dynamic movements, making this method suitable for assessing posture when workers operate the ankle.
2. The study focused on examining the load of FFB carried by workers to TPH, which resulted in poor posture that interfered with the comfort of the workers. The activity was carried out for approximately 7 hours, and each worker had a target of covering an area of 2.5 to 3 hectares;
3. Data collection was carried out using *the Nordic Body Map* (NBM) method by filling out a questionnaire and being filled out by 11 workers who operated the angklong;
4. The research using the Nordic Body Map method can then be further evaluated, with a proposal for improvement, and the posture identification method using REBA can be employed. REBA is an ergonomic risk assessment method for evaluating the risk of musculoskeletal injuries that may arise from an unergonomic working position.

Prototype Loading Tool (Corner)

1. Identification of problems related to MSDs in oil palm plantation operators, as well as preliminary studies related to the use of toke aids in the extraction of existing FFB and potential modification of tools;
2. Formulation of problems to strengthen innovation in the development and modification of standardized corner aids to reduce the risk of MSDs;
3. The questionnaire used contains question items about complaints related to body parts experienced by operators when taking the FFB conventionally. The Nordic Body Map and REBA assist data processing. Data collection was carried out by completing *the Nordic Body Map* questionnaire.
4. The process of designing ergonomic aids is supported by *SolidWorks software and the analysis of comprehensive research data, enabling a deep understanding of the design results.*

RESULTS AND DISCUSSION

Egrek

The initial stage of oil palm harvesting is planning for harvesting. The initial stage carried out by the harvester is to position the egrek right on the part of the oil palm fronds that can be cut. Positioning the egrek on the oil palm needs to be in the correct position because not

was conducted by taking photos of the tools and conducting brief interviews with the harvesters about the tools they used daily.



Figure 2. Egrek

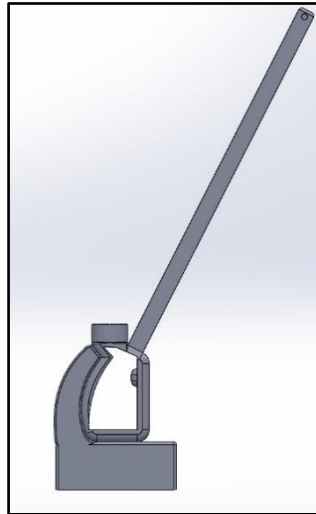


Figure 3. Prototype Bottom



Figure 4. Top Prototype

Figure 2 is an egrek aid used by PT Perkebunan Kelapa Sawit X using two extender sticks. The sticks used, which are paired with a total of two fruits, have a length of eight meters because the tree being harvested is approximately nine meters in height. At the end of the egg stick, a black rubber wrap is used by the harvester to hold the stick in place, preventing it from being slippery. The rubber is a modification of the harvester itself because the factory stand does not have a good grip, and often the egg escapes from the harvester's grasp. Ergonomics is a tool used by harvesters to facilitate oil palm harvesting, but the calculation of these methods yields unfavorable results, which can lead to MSDs (Nasir et al., 2015; Sulistyowati, 2020; Firmansyah, 2020).

Figure 3 is the bottom of the prototype. The bottom features a handle for the right hand with a button for cutting, and a handle for the left hand, allowing this tool to be adjusted in tilt safely and more ergonomically. Under the handle, there is a battery holder to move the dynamo. The dynamo in Figure 3 can be moved because it is connected to a battery by a cable that generates power. The dynamo can move the gear after the power is distributed, allowing the gear to rotate and, in turn, move the lower axle. The dynamo can move by pressing the trigger or button on the handle for the right hand. If the button is released, the egrek stops immediately, even though the fronds have not been successfully cut.

Figure 4 is the top of the prototype of the auxiliary design improvement. In Figure 4, it can be seen that there is a chain, similar to a saw, to facilitate cutting palm fronds. At the top

of the egrek there is a cover to keep the sharp part of the egrek and chain from injuring the user. The cover serves as a safety measure for the user or people around them, preventing injury. At the top, there is a gear that functions to move the chain, allowing it to cut the fronds easily.

Tojok

The graph in Figure 5 shows that the body parts of the study respondents who had the highest score values were the left shoulder, right shoulder, left hand, and right hand, with a value of 3.5. Based on the results of interviews with the six respondents at PT Perkebunan X in Sukabumi, the pain complaints occurred during the FFB removal process. The limb must withstand a reasonably heavy load repeatedly, with an average of 26 kg. The average number of fruits put in the truck is 300 pieces per day.

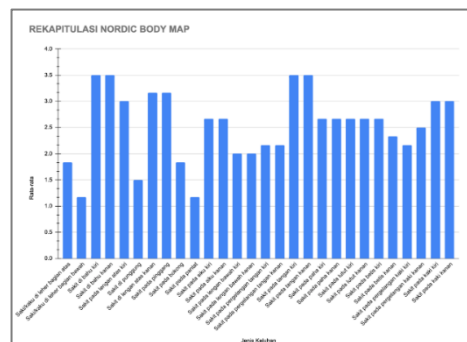
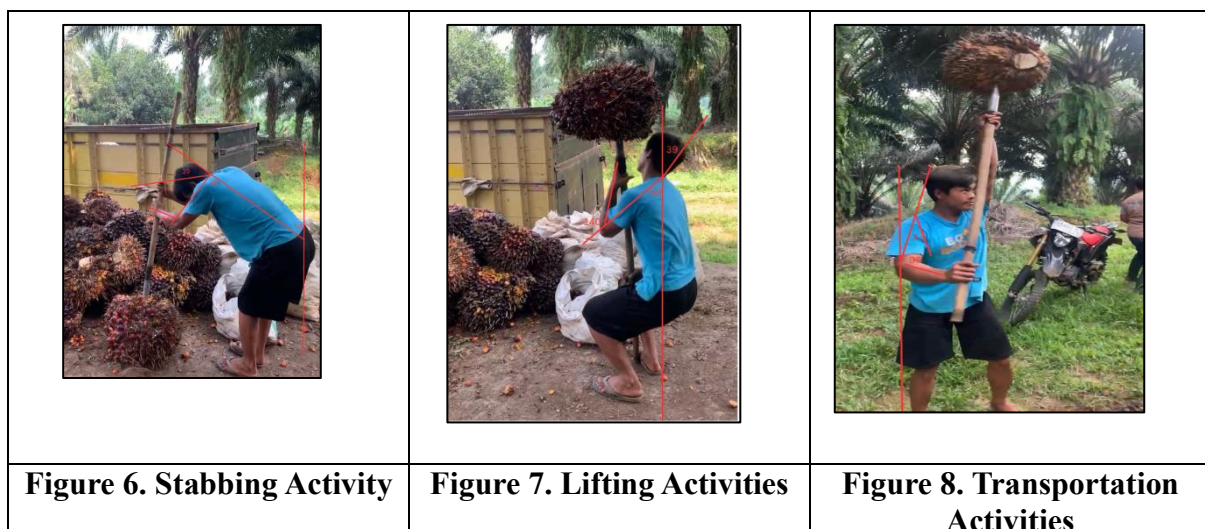
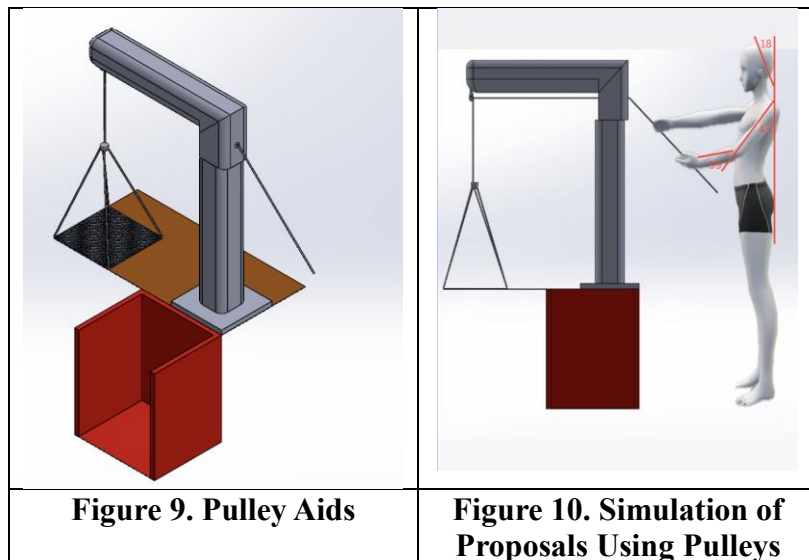


Figure 5. Nordic Body Map Questionnaire Recapitulation Chart Score



The process of stabbing the corner into the FFB is carried out by the operator, who holds the corner handle firmly and directs the end of the corner to the center of the FFB,

requiring considerable energy consumption. Next, a picture of the second stage will be attached, namely the process of removing oil palm fruits. Based on Figure 6, the angle formed on the operator's body during the process of piercing the corner against FFB is obtained. The results of the REBA calculation for Parts A and B are as follows. Part A represents the neck position, which forms an angle of 39° ; the trunk position forms an angle of 69° ; and the legs position falls between the angles of 30° and 60° . The results obtained in Part B indicate that the upper arm position forms an angle of 88° , the lower arm position forms an angle of 68° , and *the wrist position* is in a straight position. After the angle is made, the result of Part A is added to the *load score* of +0 because the load held by the operator has a mass of less than 5 kg. In the results of Part B, +0 is added because the operator's handling when stabbing is quite good.



The results obtained in part A indicate that the neck position is in the corner area, specifically 0° - 20° , and the trunk position falls into the perpendicular category, which is also around 0° - 20° . The *legs are* in a straight position. The results obtained in Part B show that *the upper arm position* forms an angle of 43° , *the lower arm position* forms an angle of 99° , which is more than 60° , and *the wrist position* is in a straight position. After the angle is made, the result of Part A is added to the load score of 2 because the load held by the operator has a mass exceeding 10 kg. In the results of Part B, +0 is added because the operator's *handling* is quite good when transporting. The final REBA value can be obtained by adding an activity score of +0 to a value of C with a score of 12 (indicating a very high risk for MSDs). To reduce the REBA value, a pulley is proposed. The results of *the final* assessment of the REBA *score* for

posture using pulley aids were 6. By using a corner aid or a pulley aid, the worker's body position can be adjusted to be more ergonomic, making them feel more comfortable.

Angkong

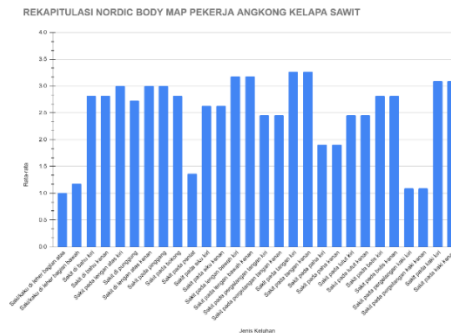





Figure 11. NBM Recapitulation Chart of Angkong Workers

The results of REBA, the initial condition when lifting the angkong (Figure 12), obtained a score of 12, and when pushing the angkong, obtained a score of 11. The score is included in the very high level of risk that needs to be fixed now. Therefore, it is necessary to draft a proposed improvement to reduce the risk of musculoskeletal disorders (MSDs) and poor posture among workers. The draft improvement proposal (Figures 13 and 14) was made in the form of a non-physical *prototype* using CAD. The proposed plan involved adding height to the angkong handle. The height increase was made considering the average height of the harvest worker, who was 165 cm tall. Therefore, the measurement of the hip height of Indonesians was taken using the 50th percentile of the Indonesian Anthropometric Data, yielding a value of 87.3 cm. The proposal to increase the height of the handle is more ergonomic, so that workers do not have to bend over when operating the angkong. The proposed design involves adding small wheels to the back of the angkong. The wheels used in the angkong are also considered for strength when carrying to temporary shelter for oil palm fruit and shock resistance. Shock-resistant wheels will help reduce vibration so, it can reduce damage to the oil palm fruit that can occur due to shocks. Additionally, it can maintain stability and increase worker comfort, preventing fatigue and injury due to constant vibration.

		
<p>Figure 12. Position of Workers when operating Angkong</p>	<p>Figure 13. Angkong Improvement Proposal Plan</p>	<p>Figure 14. Simulation of Angkong Repair Proposal</p>

The smaller wheel size can also help when the angles turn so that it becomes easier and sharper. In addition, it can help distribute the load more evenly because it prioritizes the load on the larger wheels and for the rear wheels helps to balance the load without adding more height. With a smaller wheel design, it can help workers to reduce the force expended as well as strain on the back and muscles when lifting and pushing the hips. In addition to the wheels, there is also an addition of Ergogrip in the handle which can be seen if it is in the form of four arches. The arch functions to place the four fingers, namely the index finger, middle finger, ring finger, and little finger to make it more comfortable when operating the angkong. The ergogrip is designed to provide a more comfortable grip and reduce pressure on the hands and wrists when transporting heavy loads. In addition, it can reduce fatigue on the hands and arms. The Ergogrip design can provide a more ergonomic grip, with a better grip, making it easier to operate when turning on uneven surfaces. The design can also help prevent injuries due to the repetitive work system so that it can reduce the risk of wrist pain. The material and shape used are specifically designed to be anti-slip, ensuring the hand does not slip easily when holding the pole. This means that even when the hand is sweaty or wet, the handle will still provide a firm and secure grip. Proposed design of improvements for increasing height on the angle handle, wheels on the back of the angle, and Ergogrip on the angle handle.

The results of the simulation of the proposed improvement indicate that the worker's posture becomes more upright than in the initial condition. This upright posture is evident from the head to the shoulders, neck, legs, and wrists. The results of the REBA score after the draft

of the improvement proposal were as follows: a score of 7. The decrease in score was obtained because there was a difference in posture, which became more upright from the head to the neck, then in the back and arms, when holding without needing to hold heavier weights. The results of the score decrease showed a decrease in MSDs, and the posture improved compared to before. The proposal to compare the initial condition with the draft improvement proposal is made by considering the results of the dominant pain felt. The results are further analyzed to identify areas for improvement in the painful parts.

The draft improvement proposal was developed because it examined the results of the posture of workers who experienced pain in specific parts of their body. This design takes into account the position of the worker when operating the angkong in a dynamic or moving state. The first draft proposal is to raise the handle on the angkong so that workers do not bend too much when operating the angkong. The angkong grip can help improve the worker's posture. Consideration in raising the handle is that the field's soil is not too undulating from the FFB transfer position after cutting to the TPH, allowing workers to use it comfortably. The second proposed design of the repair is to add two small wheels at the back, considering that the weight felt affects the pain in the worker's hand.

The measurements given also consider the 50th percentile of Indonesian hip height, which is 87.3 cm, because no height is too extreme for workers. This size is also designed to prevent the worker's hands from bending too much upwards, as this can interfere with pushing the angkong. The two small wheels can help stabilize the load and distribute it to the larger wheels. When pushing the ankles, workers no longer have to lift excess weight on their hands. The last draft proposal includes the addition of Ergogrip to the angle handle to help provide comfort for workers' hands. The material used is also anti-slip, preventing it from slipping easily due to the sweat generated when operating the angkong. By using angkong, workers feel comfortable in their transportation because the REBA value is 6 (previously, the REBA value was 10).

CONCLUSION

1. Modified egrek aids have succeeded in minimizing the cases of MSDs of oil palm farmers by lowering the REBA value from high to low. The results of the identification of farmers who experience MSDs using the Nordic Body Map method are with a medium value, so they need to be improved in the future (necessary soon). Meanwhile, the results of identification using the REBA method obtained a high score, indicating

that improvement was needed. The design that the researcher has made can make it easier for harvesters to cut palm fronds and FFB.

2. The level of risk of MSDs interference in operators using Tojok aids at PT Perkebunan X was determined, resulting in the finding that operators experienced MSDs interference. The parts of the body that are often complained about are the right shoulder, left shoulder, right hand, left hand, upper arm, and waist. By using pulley aids, the operator does not need to perform shock movements to withstand the mass load of FFB, thereby reducing the risk of MSDs interference (the REBA value drops from 12 to 6).
3. The addition of height to the Angkong handle with the consideration of the hip height of Indonesians in the Indonesian Anthropometer data of 87.3 cm and the addition of small wheels at the back as a load balancer to reduce pressure on the muscles and joints in bringing FFB to temporary shelter for oil palm fruit. The addition of Ergogrip to the ankle handle has successfully provided ergonomic comfort to workers and reduced the risk of wrist injury due to pushing heavy loads. The results of the proposed improvement draft showed that the REBA score decreased to a moderate level of risk, indicating a better posture among workers than before, and thus reducing MSDs in workers (the REBA value decreased from 10 to 6).

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