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Ergonomic Analysis of Working Positions in Petis Processing with the RULA Method at UD Murni Sidoarjo

Dimas Immannulloh*, Tranggono

Department of Industrial Engineering, Faculty of Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Jl. Rungkut Madya No.1 Gunung Anyar, Surabaya 60294 Indonesia

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A B S T R A C T

UD Murni Sidoarjo is a company that focus on making petis as traditional food of Sidoarjo. But, often they experience ergonomic problems which results in Work Related Musculoskeletal Disorders (WRMSDs) for their workers. The method that used in this study, namely Rapid Upper Limb Assesment (RULA) which is a method for assessing posture, style, and movement of an activity related to upper limb users. The main objective in this study is to analyze the working postures of filters sector from petis processing industry by using Rapid Upper Limb Assesment (RULA) in CATIA V5R21 software. 5 out of 5 workers postures from filters sector indicated a high risk score of 6, indicating changes in the posture is needed to be done. Tool design with ergonomic interventions are suggested and the improved posture was evaluated using Conventional RULA Asessment and CATIA V5R21 software. From 2 asessment, the posture indicated a score of 3, indicating low risk. The results from this study indicate that awkward working posture risks can be minimized effectively using ergonomic interventions with design of working tools in solidworks software that being analyzed with CATIA V5R21 software. The limitation of this study is the tool that had been design is not used by real workers, the design of the tool is only emplimented into CATIA V5R21 software which is used for RULA asessment, the design can be realized by any future researcher for another impact not just posture but also production, performance, and the others.

*Corresponding Author
Dimas Immannulloh
E-mail: dimasiman09@gmail.com

1. INTRODUCTION

All workers from any industry, especially small industry with less safer environement have a risk of injury when working, due to how the production process, unawareness when working, work environment that is not ergonomic, and unclear work procedures that make employees in danger situation. This results to an long term injury such as Work Related Musculosceletal Disorders (WMSDs), affecting the decrease of performance and production results, as well as decreasing the company's profit. MSDs risk on workers are caused by the physical demands on their jobs. The speed to produce a product taking into account the quality, cost, and delivery, is the goal of each company, so it takes the right selection of tools to meet this goal (Herlambang, 2020). For example, workers manual lifting or repetitive movements that can be burdensome their muscles and joints (Park et al., 2021). Musculosceletal disorders (MSDs) are conditions in which the muscles getting excessive stress continuously through activities that repeated over a long period of time (Tranggono et al., 2020).

Petis, a traditional indonesian condiment is manufactured through a sequence of task that often require repetitive motions, sustained postures, and varying degrees of force application. As a small industry, UD Murni Sidoarjo have this similiar problem. From what have been seen by Author, the process manufacture of petis in UD Murni Sidoarjo have a work environment that is less than a standard of food manufacturing process industry. From not wearing work clothes or personal protective equipement, don't have standard rules of production and the worst of all is the risk of Work Related Musclosceletas Disorders (WMSDs). From what have been seen by author, the working process of petis in UD Murni Sidoarjo have procedure that can make workers have risk of Musclosceletal Disorders (MSDs) in long term. Especially in workers from filter section, they don't have APD or at least working tool that can help them to do their work. Apart from another process, this process have repetitive work for 8 hours with awkward posture position. They need to bent down to pick up the filtered shrimp head for another process.

That's why Author make this paper for exploration to analysis ergonomic of workers at UD Murni Sidoarjo that focus on filters sector, Apart from the economic dependence of Sidoarjo residents, especially residents around UD Murni Sidoarjo on the production of petis, the potential ergonomic challenges faced by workers in this industry have not been comprehensively addressed. To make clear of this potential injury from filter section workers, Author make an Nordic Body Map (NBM) questionnaire to know where exactly the discomfort of workers body at UD Murni Sidoarjo. Surveys show that many employees experience complaints in this filter section. By calculating the Likert scale per individual, it was found that 4 out of 5 workers in the filter section had a high level of risk with an average score of 72.8. Where the highest level of complaints was found in 5 types of complaints in the form of pain in the left shoulder, pain in the right shoulder, pain in the upper arm, pain in the back and pain in the waist. The graphic of highest complain of this NBM Questionnaire is show in Figure 1.

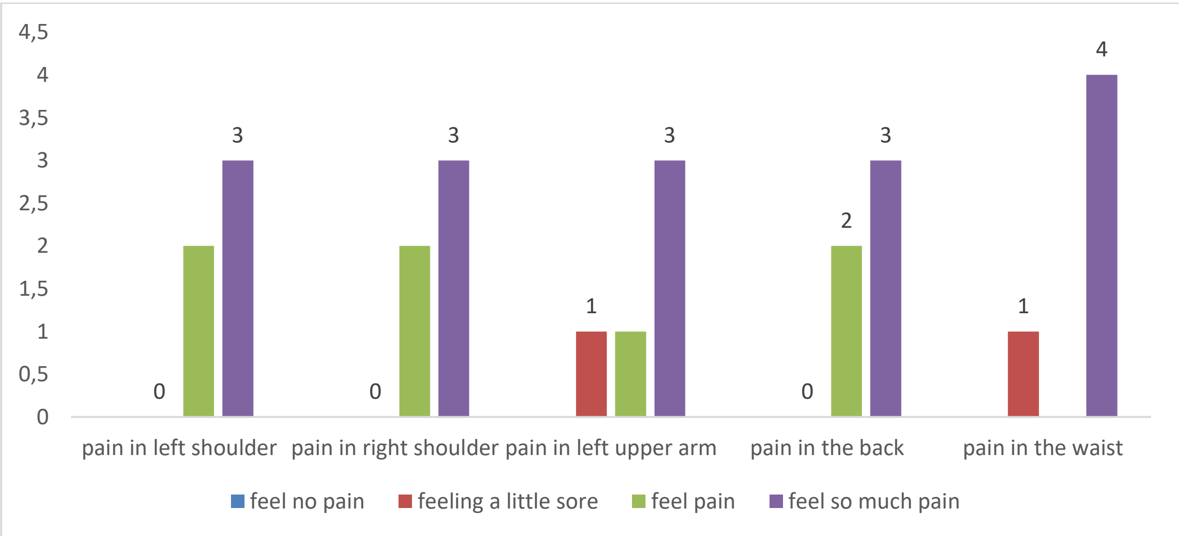

Figure 1. Highest complaint rate sample on NBM (nordic body map)
Source: internal data, 2023

From this result, we can see that the highest complain from workers especially filters section of petis production at UD Murni Sidoarjo is in their upper body. That's why Author using RULA (Rapid Upper Limb Assessment) Method for this paper. RULA (Rapid Upper Limb Assessment) is a method that aims to perform analytical calculations on the upper human body (Kurnia & Sobirin, 2020). This is where the importance of this study lies, in which the use of RULA method and CATIA V5R21 software to analyzing working posture of Employees from filter sectors at UD Murni Sidoarjo and make suggestion from result assessment. For make any future research is capable to expand the topic not only about ergonomic, this paper also intended to make not just only work posture suggestion, but also an design of working tools for make working of filters section much easier. The design of that tool will be analyzing using CATIA V5R21 to asses how ergonomic the design is.

2. LITERATURE REVIEW

The term "ergonomics" originates from the Greek words "ergon," meaning work, and "nomos," meaning rules. Ergonomics represents the rules or norms within a work system. The implementation of ergonomics is imperative due to the fact that any activity or task performed non-ergonomically can result in discomfort, elevated costs, increased occupational accidents and illnesses, decreased performance leading to reduced work productivity, efficiency, and overall work capacity (Dewi, 2020). Risk can be distinguished to several types according to the opinion of experts. Among the risk categories according to Wardhana (2010) in (Dina & Purba, 2022) include: (1) The risks identified following the assessment of the project plan, business and engineering environment in which the project is being implemented can be classified as: Undesirable delivery date, Failure to provide a written statement of requirements and There is no scope for Bad developer environment, (2) For instance the expected risks are known from prior project experience: staff changes, Failing to communicate with customers and As soon as maintenance requests have been filed, it reduces the staff effort, (3) Unknown risk. This risk can occur, but it is very difficult to identify beforehand. Anthropometrics covers measurements of body size, shape and strength in a variety of numerical data related to human physical characteristics. In order to resolve product design problems, it is essential that these data be used. Anthropometry plays a pivotal role in determining the appropriate tools and methods for operation. The alignment between workers' anthropometric dimensions and the tools they use significantly influences work productivity, fatigue levels, and overall work capacity. Body measurements are conducted in two main categories: static body dimension measurements and functional dimension measurements taken during bodily movement. The term "anthropometry" is derived from "anthro," signifying human, and "metri," meaning measurement (Winata & Suryadi, 2020). An anthropometric measurement consists of two types of measurement data, according to (Mardiana et al., 2020): (1) The measurements from the various standing positions which are in a fixed and immobile position shall be measured statically or structurally anthropometricly, (2) As the body moves, performing specific movements that are necessary to complete certain activities, dynamic or functional anthropometric data shall be collected.

Musculoskeletal Disorders (MSDs) are health issues involving the musculoskeletal system, encompassing injuries to muscles caused by sudden or sustained overloading of muscles and bones, repetitive prolonged motions, prolonged static sitting positions, and awkward working postures. These conditions can affect muscles, ligaments, nerves, tendons, and joints (Ramdan & Azahra, 2020). Musculoskeletal disorders are defined as complaints or discomfort of an individual, which differ between mild and severe pain in the musculoskeletal region, according to Tarwaka (2015) cited by (Tjahayuningtyas, 2019). It covers joints, nerves, muscles and the spinal column, which occur as a result of an uncomfortable working position. According to (Behnam Asl, et al. 2013), that cited in (Abinaya Ishwarya & Rajkumar, 2021), he investigated the musculoskeletal disorder associated with steel bar benders. In the construction site, bending of steel bars is regarded as an important work for four to six hours in awkward position and close contact with Swarf's eyes. A standardised method for the assessment of musculoskeletal symptoms has been used to perform a Nordic questionnaire involving 20 samplings.

The Nordic Body Map (NBM) is the most commonly used questionnaire for recognizing discomfort or pain in the body. Respondents complete the questionnaire by indicating whether there are any disturbances in specific body areas. The NBM is designed to capture detailed information about areas of the body experiencing pain or discomfort during work. By employing the NBM, identification and assessment of muscle pain complaints can be conducted. The Nordic body map serves as a widely utilized comprehensive questionnaire for assessing worker discomfort due to its standardized and well-organized structure. The Nordic body map is employed to identify complaints related to musculoskeletal disorders (MSDs) experienced by workers. These complaints are discerned through a questionnaire that presents various types of muscle disturbances on a human body diagram. This questionnaire enables the assessment of which muscle areas are afflicted, with a scale ranging from No Pain, Slight Pain, Pain, to Severe Pain. The results from the Nordic Body Map (NBM) can provide insights into the type and severity of discomfort, fatigue, and muscle pain experienced. The visual representation and analysis of the body map are derived from the questionnaire content (Dewi, 2020).

Occupational risk factors (such as awkward postures, repetitive tasks, frequent and/or excessive handling loads, thermal environment), along with individual characteristics (e.g. individual limitations or health problems) and social factors (such as family and economic problems, which may interfere with the motivation and attention during the work), contribute to the WMSD development. RULA is an observational method for assessing WMSD risk for the upper limbs, considering also the neck, trunk and lower extremities position during work activity. Its application involves the postures assessment adopted by the worker during tasks performance, as well as the forces exerted, the repetitiveness of movements and external loads (such as handling heavy materials) (Colim et al., 2019). RULA, which stands for Rapid Upper Limb Assessment, is an analytical method aimed at calculating and assessing the upper body. The outcome of this method is a decision level that indicates the urgency of required actions. Broadly, the procedure involves linking the angles formed by the subject's body posture with the weights provided in a table. The process consists of four key calculation stages, forming several matrices, as outlined by (Kurnia & Sobirin, 2020): (1) Matrix between Table A (containing weights for upper limb position and forearm position) and wrist posture weight. The weight conclusions are summed with the muscle force weight exerted per minute, in unity with the load, (2) Matrix between neck posture weight and Table B (containing weights for torso and leg postures). The weight conclusions are summed with the muscle force weight exerted per minute, in unity with the load, (3) The final stage is formed within Table C, representing the weight matrix between point a and point b, (3) The ultimate outcome comprises four decisions formed based on the position of weight point c within the available decision weight range. This is where the score of RULA Method is shown, it will be an score level that consist a suggestion.

McAtamney and Corlett developing RULA method in 1993. with the aim of assessing the risk factors of musculoskeletal disorders (MSDs) in the upper extremities during work activities. Three main stages are involved in conducting an assessment using this method (Gómez-Galán et al., 2020): (1) Body Posture Observation: This step is performed while workers are engaged in their tasks and can be executed through three approaches: direct observation, photography, or video recording. Postures to be assessed (those that are frequently repeated, comprising more than 10% or 25% of tasks, and those deemed the riskiest) are selected. In this observation, only one side of the body is analyzed, typically the one experiencing the most strain or risk. However, if both sides exhibit significantly different postures, both sides are evaluated, (2) Scoring: To assess body postures, angles between each body area and the vertical axis are measured. Lower extremities are not measured, although balance is considered. With the acquired data, modifications are made using various criteria, considering load factors and muscle activity to calculate the RULA score, and (3) Action Levels: In this step, based on the final score obtained during the Scoring stage, RULA have four action levels: (i) Level 1 (score: 1-2): Without action required, (ii) Level 2 (score: 3-4): Action needed but not be addressed in the short term, (iii) Level 3 (score: 5-6): Action required in the short term, and (iv) Level 4 (score: 7): instant action needs to be taken. According to Suma'mur (2009) as cited in the journal by (Salim et al., 2019), work fatigue encompasses various conditions accompanied by reduced efficiency and endurance during work. Work fatigue can lead to decreased performance and an increased risk of human errors. Several factors influence work fatigue, including inadequate Occupational Health and Safety (OHS) compliant work environments due to excessive workload and prolonged working hours. This fatigue poses sustained risks if not significantly addressed, leading to work-related stress, occupational illnesses, and workplace accidents. Work-related stress can have several impacts on workers, one of which involves physiological changes, particularly fatigue.

CATIA (Computer Aided Three Dimensional Interactive Application) is a versatile software with a broad range of functions encompassing CAD, CAM, and CAE, coupled with robust design analysis capabilities through "Integrated Design and Analysis" programming. CATIA application boasts distinctiveness as a comprehensive 2D and 3D drawing system, maintaining consistency across user interfaces, data management, database utilization, highly detailed models, and application program interfaces. CATIA serves as a powerful analysis tool for evaluating existing products or aiding in the design process. It encompasses components such as CATIA Kinematics, CATIA Image Design, and CATIA FEM (Finite Element Modeler). CATIA finds extensive application in diverse industrial domains, including mechanical design, analysis, robotics, and tooling design. The application of CATIA extends to component analysis, covering structural strength in static loads, free frequency analysis, and even comprehensive design simulations (Rojas-Sola et al., 2020). SolidWorks is a 3D CAD software developed by SolidWorks Corporation, now acquired by Dassault Systèmes. It is a widely known 3D CAD software in Indonesia, with numerous manufacturing companies implementing it. SolidWorks serves as a graphical software program for designing machine parts or assemblies, presenting them in both 3D and 2D views. It is extensively utilized for engineering design purposes, particularly for creating 3D models and drawings (Yasa et al., 2022).

SolidWorks is a mechanical design and automation software based on solid parametric modeling. It is a simple but very powerful modeling tool that enables you to convert 2D sketches into solid models. SolidWorks offers A number of tools that allow for the production of real world components and assemblies. These components and assemblies may be transformed into 2D Technical Drawings of Production in the course of this process. Moreover, you can validate your designs by simulating real-world conditions and assessing the environmental impact of your product (Dogra, S., 2023). A firm foundation for advancing the implementation of theory development is created by an effective and efficient conduct review as a research methodology (Taufik, 2020). Although many studies have used petis industry as their field study, there is a lack of research on case from filter section, other researcher intend to focus on other section. This research gap limits our understanding of MSDs risk in filter section of process manufacturing petis. Therefore, this study aims to explore working posture in petis industry, especially at filter section that may have consecuences of MSDs risk.

3. RESEARCH METHOD

This study gathers anthropometric information, a crucial component of ergonomics that focuses on understanding body dimensions such as height, weight, and proportions. This encompasses a range of factors including size, strength, speed, and kinematic aspects derived from bodily motions. Ensuring the accuracy of anthropometric data is paramount, as it serves as the foundation for designing devices. The methodology involves: achieving a substantial sample size, incorporating samples from diverse communities using a random approach, and creating generalizable insights for broader populations. This clarification of anthropometric samples is guided by key variations in human dimensions. The Rapid Upper Limb Assessment (RULA) method is employed for evaluating body postures, encompassing neck, upper arm, and back positions. Each motion is assigned a predefined score, and the use of specialized equipment is unnecessary in this assessment process. For better understanding of the step on this research paper. Figure 2. Research Stage will describe it in a simple ways of thinking. The research stage involves the process of investigating and studying this specific topic. During this stage, Author will collect and analyze information, data, and relevant sources to gain a comprehensive understanding of the subject. This often includes reading books, articles, and other materials, conducting experiments or surveys, and reviewing existing research.

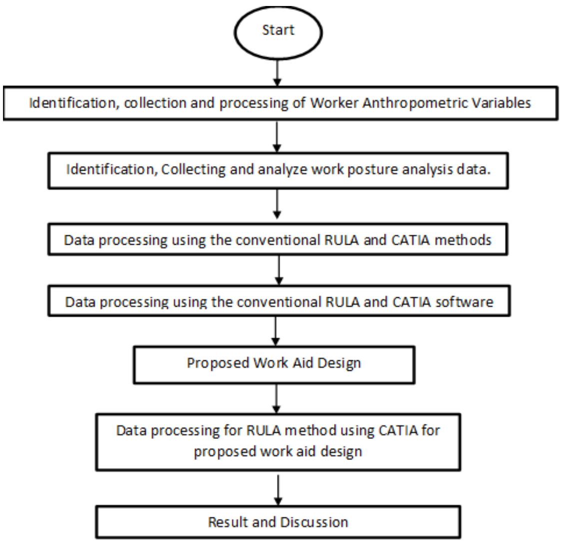

Figure 2. Research stage
Source: internal data, 2023

As mention on Figure 2, identification, collection and processing of workers Anthropometic variables and work posture is an importance step of this study. Not only this data describe the problem, but also from this data, Author using it for design of the work aid. The work aid design will be an reference for any fuirther research, not only focus on ergonomic problem, but it can be expanded to any problem like production, performance of workers, and another field of study.

4. RESULT AND DISCUSSION

The data collection involves anthropometric data gathered from a group of five workers stationed in the filters section at UD Murni Sidoarjo. Anthropometric measurements provide valuable insights into the physical dimensions and characteristics of these workers, aiding in understanding their ergonomic needs and ensuring that their work environment is optimized for both safety and efficiency. By analyzing data related to height, weight, body proportions, and other relevant factors, employers can tailor workstations and equipment to accommodate the workers' unique physical attributes, ultimately fostering a more comfortable and productive work setting. This attention to detail in the design process can contribute to reduced fatigue, lowered injury risks, and enhanced overall well-being for the workers involved.

Table 1. Worker anthropometric data (cm)

Name	Elbow Height	Upper arm length	Forehand span length	Side arm length	Elbow length	Forward grip length
Sigit	115	34	63	167	85	76
Rianto	110	32	63	165	82	74
Kasan	107	31	62	162	81	73
Muslimin	109	32	61	164	81	74
Sunarto	105	30	60	161	80	71

The worker anthropometric data is used for making product design. For working posture of the workers, will be seen in Figure 3.

Figure 3. Work posture filter sector
Source: internal data, 2023

From the figure 4. we can get results of working posture with RULA Assesssment. The assessment involved a systematic analysis of the participants' postures and movements, focusing on the upper limbs and the associated risk factors for MSDs. The RULA scores were calculated for each participant based on their observed postures, force exertion, repetition, and other relevant ergonomic parameters.

Posture Analysis, The analysis of participant postures revealed several significant findings. The distribution of posture scores indicated that 5 of workers exhibited high-risk postures, with score of 6 in RULA conventional method and with CATIA software. With RULA conventional method we used 3 major step with 2 group of assesment with table A, table B and table C, here's the result from each table (Table 2).

Table 2. Result from table A group 1

Upper Arm	Lower Arm	WRIST 1		2		3		4	
		Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	2	3	3	3	4	4
2	1	2	2	2	3	3	3	4	4
	2	2	2	2	3	3	3	4	4
	3	2	3	3	3	3	4	4	5
3	1	2	3	3	3	4	4	5	5
	2	2	3	3	3	4	4	5	5
	3	2	3	3	4	4	4	5	5
4	1	3	4	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	3	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	7	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

From these calculations, the value of group 1 in table A is in row 4. Table A from group 1 is indicate score of upper arm position, lower arm position, and wrist position.

Table 3. Result from table B group 2

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

According to those calculations, a row 4 of Table B shows data which correspond to group 2. The data of group 2 are those pertaining to assessment score for trunk position, neck position and legs position in Table B. These scores are an important source of insight to the ergonomic alignment and position of workers' main body segments when performing their tasks.

Table 4. Final score RULA in table C

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

In this table, the intersection of values between group 1 and group 2 is used to obtain the final RULA score. In this calculation, the final Rula Score is marked with a red column of 6 so that it can be concluded that if the conventional way, the RULA score is 6, then further investigation and changes are needed for the work of the filtering sector in the processing of petis at UD Murni Sidoarjo. This suggests that these postures could potentially contribute to an increased risk of developing MSDs over time.

RULA Method With CATIA Software, The integration of CATIA software into the RULA assessment process allowed for a more detailed and accurate analysis of ergonomic risks. CATIA's capabilities enabled the creation of 3D models and simulations, which provided a realistic representation of the tasks being evaluated. This digitized approach offered precise measurements of joint angles, muscle forces, and postures, enhancing the objectivity of the assessment. The digital environment of CATIA facilitated an in-depth analysis of participant postures. Joint angles and body positions could be precisely measured and visualized, providing insights into potentially risky postures. CATIA's ergonomic analysis tools allowed us to identify postures that deviated from neutral positions, and to quantify the degree of deviation. This detailed information enabled a more accurate assessment of the impact of different postures on the upper limb and spine. With CATIA, author make an mannequin simulation for better detail and results. Here we can see the mannequin in Figure 5.

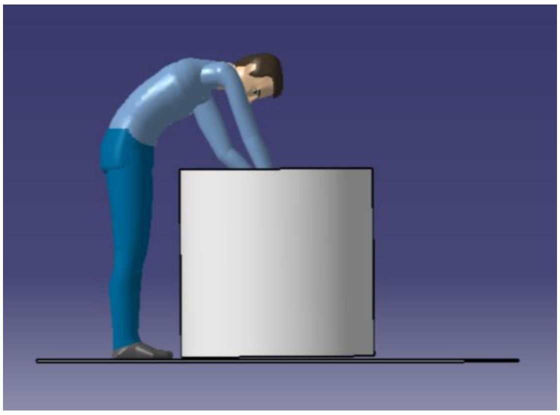

Figure 4. Mannequin posture
Source: internal data, 2023

After the mannequin's posture has been adjusted, then do the RULA calculation by selecting RULA Analysis.

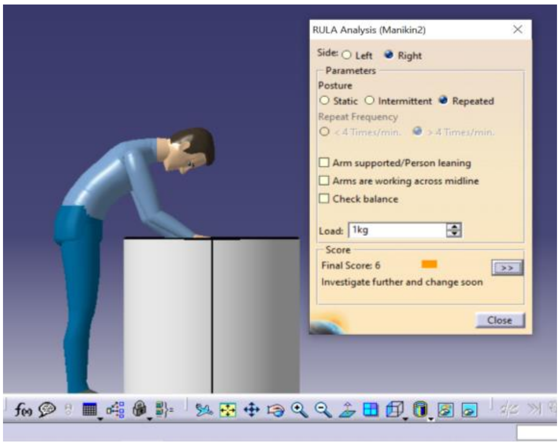

Figure 5. RULA analysis with CATIA V5R21
Source: internal data, 2023

With CATIA, Score RULA is 6. So, it is the same as score RULA from conventional Method. From these score we assume that workers need an adjustment for theirs posture. So, Author make a suggestion posture with new working tool design, and then make an RULA Analysis again for make sure that score is make an improvement, wheter is lower or higher.

Design Working Tool, for analyze the better posture for workers in filter section of petis processing at UD Murni Sidoarjo, Author make an design of workig tool with solidworks software. The result of the design is show in Figure 6.

Figure 6. Design of working tool
Source: internal data, 2023

This design will be used for RULA Analysis with CATIA V5R21. In CATIA, RULA Analysis is easy, using the design then input it in Ergonomic features of CATIA V5R21.

Figure 7. Proposed work posture with product design
Source: internal data, 2023

The result of RULA Analysis with ergonomic feature from CATIA V5R21 it show in Figure 8.

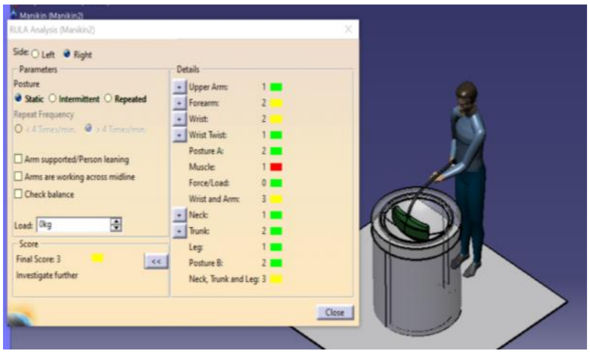

Figure 8. RULA Analysis
Source: internal data, 2023

The result of the RULA analysis indicates a score of 3, signifying a moderate level of ergonomic risk associated with the assessed task. This score suggests that while certain aspects of the task display deviations from optimal ergonomic conditions, they do not currently pose an immediate high risk of musculoskeletal issues. However, it is essential to address the identified ergonomic concerns to prevent potential discomfort or strain from escalating into more significant problems over time. This moderate level of risk underscores the importance of implementing targeted interventions to optimize posture, reduce force exertion, and minimize repetition, ensuring the well-being and long-term health of individuals engaged in the task. Regular follow-up assessments and educational efforts can contribute to maintaining a safer and more ergonomic work environment. Compare to other study that focus on making tools in stirring section of petis production, this study have another point of view in filters section. For example, study from (Sutadi & Putra, 2022) focus on making design machine of mixing petis dough which the have succeed to make machine that improve the production process. Different from this study, that focus on filter section with results of improve working posture from 6 to 3 level RULA. From this study, UD Murni Sidoarjo now can use the design of working tools to be manufactured. The company will not be worried of wasting money in this design, because its already being studied that this working tool will improve the work posture of filter sections.

5. CONCLUSION

Overall, the success of our study to improve work posture in filter section in petis production have success, which where we reducing the RULA score from 6 to 3 after implementing design changes underscores the potential of technology-driven ergonomic interventions. This approach, combining RULA analysis with CATIA software, holds promise for organizations seeking to optimize workplace conditions and prioritize the health and well-being of their workforce. Further research and implementation of similar strategies are recommended to continue advancing the field of ergonomic assessment and design.

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