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A Study of the Design of Lifting Trolley for the Suspending Agent Pouring Process in Chemical Industry

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Abstract. *The raw material preparation process in the chemical industry is still done manually by pouring the suspending agent. Workers pour 20kg boxes with a frequency of 20-30 boxes every day. These activities have the potential to cause musculoskeletal injuries. The purpose of this study is to provide an assessment and design a lifter as a conveyance that has the potential to reduce the risk of musculoskeletal disorders. This study used the Nordic questionnaire to determine the prevalence of musculoskeletal complaints, REBA to assess work posture, and QFD as an approach in designing the lifter. Based on the results of the questionnaire, the most complaints were felt in the upper body. And based on the assessment with the QEC method, the average total exposure received by workers is 64.63%. This is evidenced by the results of the assessment of 60 work postures during the suspending agent pouring process which obtained the highest REBA mode value with a score of 8 (high risk). Based on the QFD method, this lifting trolley produces 11 target specifications. After simulating the design of the lifting trolley, the REBA score decreased to 3 (low risk). This shows that the designed trolley has the potential to be applied to reduce the risk of musculoskeletal disorders in workers in the chemical industry.*

Keywords: *Ergonomic; MSDs; REBA; QEC; QFD.*

I. INTRODUCTION

Body posture analysis can be a useful technique effective for assessing work activities. Posture is not natural and lasts for a long time can cause overload on the muscles (de Almeida Fischer et al., 2022). Frequent unnatural work postures caused by the inappropriate size of the process equipment with operator anthropometry. it can causes complaints of Musculoskeletal Disorders (MSDs) thus affecting operator performance (Pegiardi & Setyaning Handika, 2017). Work-related Musculoskeletal Disorders (MSDS) are a collection of health problems that are common in workers compared to the lay population that are not caused by acute trauma or any systemic disease (Shariat et al., 2016). MSDS is a disorder of the bone, muscle, joint, ligament, nerve, and blood vessel systems in humans. These disturbances can occur due to repetitive movements, vibrations, and positions when humans carry out certain work activities (Korhan & Ahmed Memon, 2019) .MSDS is believed to be a major factor in workplace absenteeism, reduced quality of life, changes in the quality of work, and increases in these disorders (Besharati et al., 2020). MSDS is a problem that causes discomfort in striated muscles, the junction of two bones (joints), and other soft tissues (tendons and ligaments) ranging from mild to severe complaints. Complaints emerge due to dreary stacking in a stationary position over a long-term or working period. Visit persistent or anything taking care of exercises including overwhelming weights can lead to an increment within the chance of musculoskeletal clutters (Davison et al., 2021). This musculoskeletal disorder can take the form of muscle fatigue (muscular fatigue) due to the accumulation of lactic acid production from fast twitch muscles or depletion of glycogen in muscle fibers (Sarifin G, 2010).

At the same time, losses were also experienced by the company, namely a decrease in the company's productivity level and added costs incurred by the company for treatment operator (Kapitán et al., 2018).

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The raw material preparation process is one part of the production process, this process still uses manual material handling so physical strength is needed. In the raw material preparation process, workers lift, carry, and pour box weighing 20 kg with a pouring frequency of 20 to 30 boxes every day. Based on the results of observations, the abnormal and awkward working posture, while the workers were carrying out these activities, caused one of the workers to experience musculoskeletal disorders in the lower back. If the pouring of raw materials is carried out continuously without intervention in eating ergonomics, it will cause musculoskeletal injuries in the future and reduce productivity levels. So it is necessary to design alternative lifters that can reduce the risk of musculoskeletal disorders due to the raw material preparation process. The design of gear and facilities should consider the human side of administrators to guarantee that staff can securely, productively, and comfortably total different assignments. In this way, the relevant body parts of the administrators should be in a comfortable pose and movement run, and the format relationship of the significant gear ought to be analyzed (Chen et al., 2023). The lifter design is focused on REBA, QEC, and QFD data.

Based on Fig 1. It can be seen that the worker's posture poses quite a dangerous health risk, so this activity needs attention. Workers pour 20 to 30 boxes each day with manual handling, taking between 60 and 120 minutes to complete. Musculoskeletal disorders (MSDs) caused by dangerous manual handling makes a significant health burden globally (McCormack et al., 2021).

Figure 1. Illustration of Pouring Box Process

The advantage of manual material handling compared to material handling that uses tools is the flexibility of the movements carried out. However, behind the overall success, there are shortcomings, namely in terms of safety and occupational health. Manual material handling activities have a high potential for accidents because in this activity there will be direct contact between the material and human body. High splints on the muscles and spine of the skeletal system can result in overstrain in the muscles, especially in the neck muscles and spinal cord and in other parts of the spine. Besides that, the use of work postures that are not physiological or unsafe and large weights can cause spinal cord injuries in the work (Purnomo, n.d.).

II. Research Method

There are some of the methods used in this research.

1. *Instrument Survey of Musculoskeletal Disorders.* Instrument survey of musculoskeletal disorders is an ergonomic measurement method that includes preparation for carrying out measurements and evaluating the results of ergonomic measurements in the workplace (BSN, 2021).
   This survey was attended by suspending agent pouring workers, with 3 question sections each at different times, namely frequent pain for 12 months, severe for 12 months, and pain in the last 7 days. The question concerns the painful part of the body, mentioning a total of 20 body parts. The results of measurements and evaluations of potential ergonomic hazards are used to identify potential health problems due to ergonomic hazards.
   Further, it is necessary to have an ultimate work posture assessment to know the level of risk of the work posture in relation to the danger of developing musculoskeletal injuries.

2. *Working Postur Assesment.* Using method REBA to analyze the working posture of the pouring process box for suspending agent. REBA has been created to fill a seen require for a practitioner's field device, specifically planned to be sensitive to the type of unpredictable working postures found in health care and other benefit businesses (McAtamney & Hignett, 2004). The activities documented during one cycle, starting from lifting the box, carrying the box to pouring the box. From the video has been documented, total of 60 photos were selected in 1 work cycle to obtain different and varied work posts.

   Then analyze the risks of working postures with the 60 photos that have been obtained, then carry out the analysis using ErgoFellow 3.0 software. After obtaining the risk value from the photo, the next step is to calculate all work postures and group them with percentage into low risk, medium risk, high risk, or very high risk for each work posture.

   This research also using QEC method, has a high level of sensitivity and usability and widely accepted reliability (Li ' & Buckle ', 2015). The method used to analyze body posture loads felt by workers is intended for operators or observers. Quick Exposure Check could analyzes exposure on the back, shoulders/arms, wrists, and neck. This method also evaluates exposure based on duration, workload, and level of work difficulty which are included in the assessment criteria. QEC helps to prevent musculoskeletal injuries during work experienced by workers who manually handle materials, such as repetitive movements, pressing forces, wrong posture, and work duration.
3. *Ergonomic Intervention Design*. Designing work tools using the Quality Function Deployment (QFD) method so that the tools match what is needed, then creating a house of quality matrix by spreading questions to workers starting from customer needs to the technical matrix. QFD appears to be a methodological device equipped to supporting greater ergonomics thought in product design because its points are to protect client needs all through the design process, to advance communication between plan performing artists (engineers, ergonomists ,users, etc.) and to highlight possible contradictions between the different design parameters (Marsot, 2005). After the design is obtained as intended, and it designed using Solidworks software. The design for work tools will be simulated in CATIA softwere. This result of simulation are compared with existing working conditions, and work postur assessment are carried out using REBA method.

III. Result and Discussion

Analysis of the Prevalence of Musculoskeletal Disorders

Based on Fig 2. The results of questionnaire showed that the part of the body with the most complaints during the last 12 months was predominantly the upper frame. From the data obtained, it was shown that the highest average pain relief was in the right shoulder, left shoulder, right elbow, left elbow, right arm, upper back, lower back and right hand with a 100% cervical spine, neck with a value of 88%, left hand with a value of 75%, hip with a value of 50%, right calf and right thigh with a value of 25%, right knee with a value of 13%, and other body parts with a value of 0%. Disorders of the lower back, shoulder, and neck caused the highest rate of sick leave taken from work (Acaröz Candan et al., 2019).The factors that cause the high prevalence of muscle-skeletal results are due to excessive

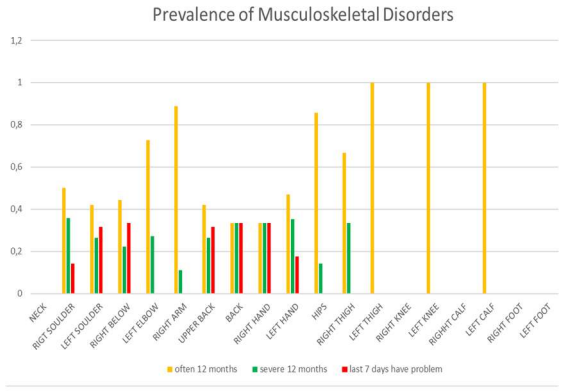

Figure 2. Prevalence of Musculoskeletal Disorders

muscle performance.

Previous research explains that carrying box activities by workers in PT XYZ experienced the greatest complaints (very painful category) in the hips, upper arms, lower arms, and wrists (Tungga et al., 2021). Another case, explains that in PT Sari Warna some workers complained that their bodies felt sore and that they had been injured several times, and often felt pain in the back, waist, calves, and back of the neck after activities lifting and lowering boxes. This is because the work was done repetitively for a long time, namely 7 hours and the load lifted is quite large, reaching 24 kg, which means it exceeds the loading constant of 23 kg. large enough to reach 24 kg which means it exceeds the constant loading of 23 kg, in addition to the value of the horizontal variable that occurs in this work is also quite large up to 24 kg. The horizontal variable value that occurs in this work is also quite large up to 97 cm even though the optimal distance is ≤ 25 cm (Salsabila, 2022). Other cases, explains in PT Indah Kiat worker the work of preparing paper ream boxes have weight 12-24 kg manually arranged on pallets, worker feel sore on the waist and back occurs as a result of poor work posture and heavy lifting loads the big one (Anggraini, 2016).

Manual pouring work requires large muscle movements. Manual pouring activities require pouring 20-30 boxes of suspending agents every day with a weight up to 20kg per box. Therefore, if workers get fatigue, it is recommended to take breaks at certain times.

Analysis work posture with REBA and QEC

The Tabel 1 can be seen, that lifting box activities have the highest risk of working posture. Meanwhile, carrying and pouring postures are included in the medium category. Medium risk positions require an immediate change of work position and further examination to avoid MSDS. The job of pouring suspending agent is a high risk. So acitivity pouring boxes need to be an investigation and implementation of change.

The results of this research are in line with previous research by Sukendar (2022) examined the activities of transporting hazardous waste from one workstation to another with manual material handling . This activity was assessed for work posture using the REBA method resulting in a score of 8 and was also included in the high risk category. Another research conducted by Kosasih (2019) examined the activity of transporting liquid containers from one workstation to another with bare hands. This activity was assessed for work posture using the REBA method resulting in a score of 9 and was also included in the high risk category (Kosasih et al., 2019). Other cases, explains that transfer the sheet metal from the storage rack to handling device and transport the sheet metal from the storage rack to laser cutting machine with manual handling. This activity was assessed for work posture using the REBA method resulting in a score 11 and 12, was also included in very high risk, implement change (Radin Umar et al., 2019).

The results of QEC assessment from eight worker exposed to risk musculoskeletal disorder is average 64,63% include in high risk category. It shows to high risk category it must be to need an investigation and implementation of change. included in the high category, improvements are needed soon as an effort to reduce the risks experienced by workers and reduce the emergence of disturbances musculoskeletal in workers. Improvements that can be made are changes and improvements to work methods, holding regular training for workers so they can apply work methods that comply with ergonomics principles to reduce complaints and resulting injuries from wrong working postures (Pambayung et al., 2018).

High score result from REBA and QEC are due to workers doing activites in awkward and

Table 1. REBA result for work postur on Pouring Suspending Agent

Activites	REBA score	Description
Lifting Box	8 (High Risk)	There needs to investigation and implementation of change
Carrying Box	7 (Medium Risk)	There needs to be further investigation and change as soon as possible
Pouring Box	4 (Medium Risk)	There needs to be further investigation and change as soon as possible

unnatural posture. This several factors that score result is high are awkward body posture and carrying a load weighing 20kg with a frequency of pouring 20-30 boxes, the position of the hopper is rather low so workers pouring box have to bow down which makes it difficult for workers to get a normal body position, not having an ideal grip on the box during this activity and the pouring location is narrow so one foot has to stand on top of the hopper, making the other foot unstable.

The Result of Designing Tools

Concept proposal ergonomics tools proposed by researchers are expected to be able to reduce the risk MSDs injuries and improve working posture on worker (Kusmasari & Mustaqim, n.d.). New tools designed considering size based on anthropometric data and shape ergonomic. Tool design can reduce loads that are lifted manually to reduce the occurrence of MSDs. in principle product design, anthropometric data can be used to determine the dimensions of the product to be designed. The new design of the work tool is called the trolley lifter. trolley for

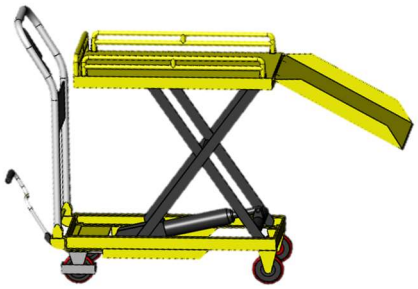

Figure 3. Trolley Lifter Design

transportation were evaluated based on the following factors: type of equipment & load weight (kg), body posture, handgrip, work pattern, travel distance, condition of equipment, floor surface, obstacles along route and other factors (Esteban et al., 2020).The result of QFD tools are described next. Using QFD tool, the customer or user wants and needs are transformed to technical requirements by formulating initial specifications of the product and the possible materials to be used (Esteban et al., 2020). Specification are The dimensions of the table lifter are 900x540x1010 mm, full cylinder handle with a length of 85 cm, made of carbon steel and the handle is made of stainless steel, Using a hydraulic system to raise and lower the lifter table, components are connected using a welding system, wheels stopper made from polyurethane so that the wheels are locked when not use, round guide rail made of stainless steel, trolley height uses the 50th percentile is 103 cm, distance between trolley handles using the 50th percentile is 45 cm and width of the trolley handle using the 95th percentile is 17 cm. Ergonomic consideration requires the arm rest for applying the push/pull effort at the height nearing the human hip height ample foot clearance below the bottom plate (Singh & Deivanathan, 2016).

Simulation using this trolley is after the worker carries the box onto the lifter table, the trolley is driven to the pouring place (hopper). The bending pouring activity is no more, because this trolley is now equipped with a telescopic hydraulic scissor. Telescopic hydraulic scissor is a tool for raising and lowering tables according to workers' needs, so that workers do not bend when carrying, pouring or lifting. If you want to raise the lifter table, just step on the pedal under the trolley, and if you want to lower the table, just press the lever on the lifter trolley handle.

Analysis of the trolley's potential in reducing of risk

In this simulation using CATIA software and use REBA method, there are three activities involved in using the proposed tools, namely lifting box, carrying box and pouring box activities. Then, three simulations were carried out to assess the posture of the operators involved. Based on Fig 4, The final score for working posture pouring the box using trolley lifter is 3 (low risk), get decrease score 1 point from the initial working position with manual handling score 4 (medium risk).

Based on Fig 5, The final score REBA working postur carrying box using this trolley lifter is 2 (low risk), get decrease score 5 point from 7 point (medium risk) with using manual handling.

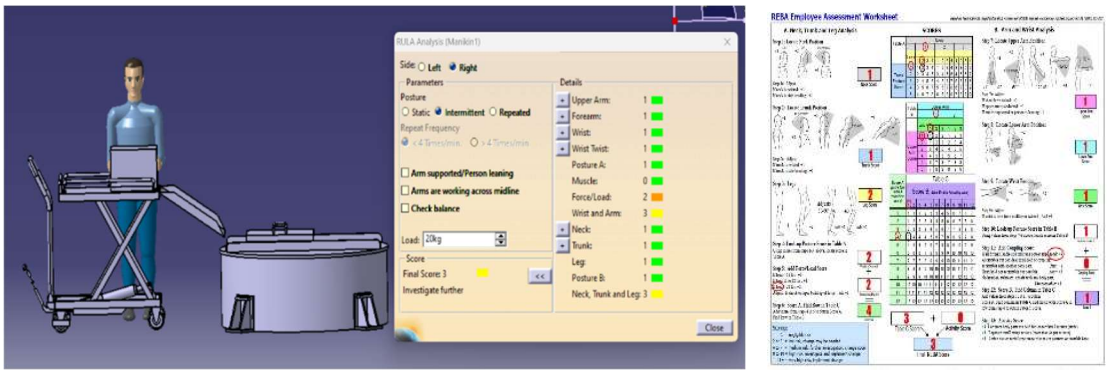

Figure 4. REBA Final Score Pouring Posture on Simulation Using a Trolley

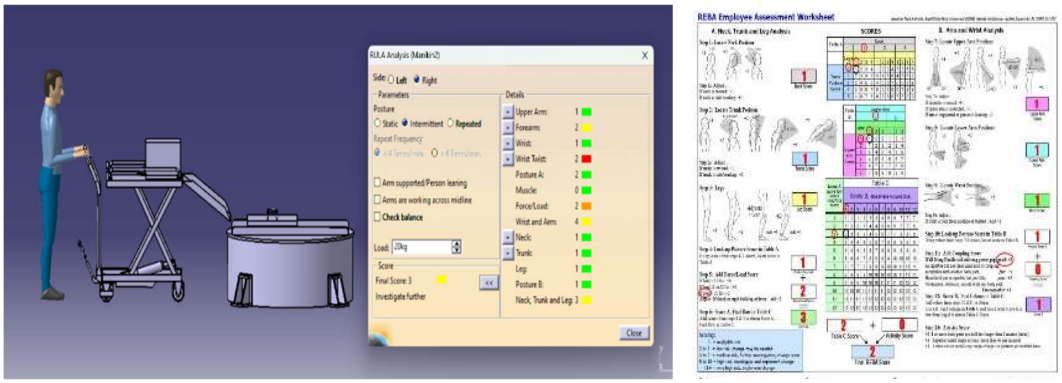

Figure 5. REBA Final Score Carrying Posture on Simulation Using a Trolley

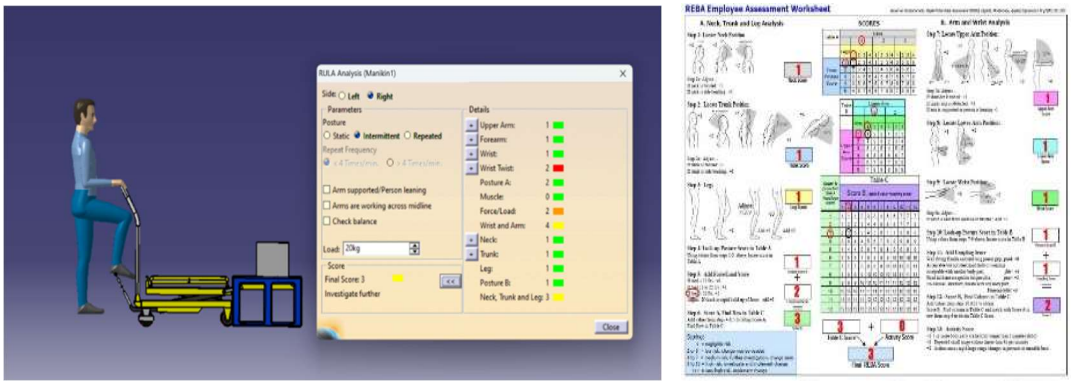

Figure 6. REBA Final Score Lifting Posture on Simulation Using a Trolley

Based on Fig 6, The final score REBA working postur lifting box is 3 (low risk) with using new design trolley lifter, and get decrease score 5 point from initial working position with manual handling is 8 point (high risk).

The trolley-lifter model has the potential to decrease physical effort on the operators. Using the new trolley lifter we got low score, this mean that trolley lifter can reduce the level risk of musculoskeletal injury, due to change working position from awkward and unnatural position to normal or ergonomic position.

The trolley lifter has functional advantages there are, reduces habit of bending and squatting, because this trolley could minimizes pouring and carrying box, worker no longer hold the box with their hands when pouring, just stand next to the lifter while pouring with stand up, More effective for pouring process, because the trolley lifter table can be raised and lowered as desired, and more safe for user, because there is a

guide rail and tire stopper so that it is more safety and secure.

IV. CONCLUSION

Instrument survey musculoskeletal disorders, worker complaints are mostly in the upper section of the body, based on the mode of recapitulation of work posture assessment using the REBA method, lifting activities are included as high risk. Meanwhile, pouring and carrying activities are included in moderate risk. Based on QEC questionnaire calculations, the average total exposure received by workers is 64.63%, this indicates need to investigation and implement of change, and based on the results of visual simulations with CATIA software, there was a decrease in the highest score in lifting box posture, in initial working with manual handling get score REBA 8 (high risk), decreased by 5 point to 3 (low risk) after using the new Trolley lifter, this mean that trolley lifter can reduce the level risk of musculoskeletal injury, due to change working position from awkward and unnatural position change to normal or ergonomic position.

Research on the design of handling chemical material bag aids was carried out by Yadi et al. (2018), for ergonomic intervention creating jack adjustable tables and conveyors for work activities with bag chemical material. However, in the development process, it does not use the QFD approach, the product has not been adjusted to the needs and desires of its users. The design of the jack-adjustable table and conveyor does not use anthropometric data, as a result, the size of the tool design is not suitable and feasible for the worker's body so it is not ergonomic. Using a trolley lifter is more flexible and suitable for limited space, using a conveyor requires a large space and costs a lot of money.

This research can be continued by carrying out further analysis of the design of tools which can be in the form of material analysis and financial analysis.

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