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DIGITAL HUMAN MODELING (DHM) FOR COMPUTER-AIDED ERGONOMICS ANALYSIS IN THE HORTICULTURE INDUSTRY

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ABSTRACT

In Indonesia, the production of water spinach increased by 9,24% from the last year, which was reasonable because water spinach was one of the most sought-after and popular types of vegetables. The farmers have exposure risk factors of work-related musculoskeletal disorders (MSDs) owing to poor watering of plant workstations using manual methods. This journal aims to explore the application of computer-aided ergonomic analysis and digital human modeling techniques in optimizing the workstations of farmers in water spinach plantations. This paper compares ergonomic scores for body posture farmers before and after improvement. Improvement was done by replacing the manual ball valve with motor operated valve (MOV), controlled (opens and closes) by farmers' phones. Before and after improvement, body posture farmers are converted to digital human modeling and analyzed by CATIA and RULA analysis tools. The result of this paper comparing before and after improvement results in a percentage reduction in RULA Scores of 75% from a 4 to 1 value.

Keywords: posture analysis; musculoskeletal disorders; digital human modeling; RULA; CATIA

1. INTRODUCTION

In Indonesia, the horticulture industry was one of the most livelihoods place due to Indonesia having fertile soil. Production of water spinach increased by 9,24% from the last year, which was reasonable because Water spinach was one of the most sought-after and popular types of vegetables [1]. To have good-quality products, water spinach plants should be given good water treatment, especially in water distribution. Water balance treatment booster water spinach growth than conventional treatment [2].

The watering plant was an essential activity in the horticulture industry. Watering plants in a water spinach farmer group Mekar Jaya Karangnunggal have a modern watering distribution system evenly distributed by sprinklers through the pipe. To ensure the watering distribution system performs well, the watering system was divided into three sections to keep uniform water pressure by ball valves. A farmer regulates water flow daily by repeatedly opening and closing the ball valves from each section every morning and evening. These farmers perform this activity in a squatting position, stooping position repeatedly, and exerting force, as shown in Fig.1. Thus, the farmers have exposure risk factors of work-

related musculoskeletal disorders (MSDs). A workstation such as men, methods, materials, machines, and the environment with a squatting position for a long time or repeatedly was an uncomfortable condition for workers. It increases risk factors for work-related musculoskeletal disorders (MSDs) [3]–[6].

Figure 1. Squatting and stooping position in opening and closing ball valves activity

Digital Modeling Human was converting the actual human posture method to digital modeling. Digital modeling was used to analyze work human posture. Ergonomics was a rare subject about the relationship between body posture position and workstations such as men, methods, materials, machines, and environment. The revolution of Industry 4.0 forces the industry to analyze by virtual modeling because it has low cost and increased productivity analysis. Therefore, CATIA and RULA Assessments perform ergonomics analysis with digital human modeling. The manikin for digital human modeling was modeled in CATIA software and RULA. RULA Assessment was a practical assessment for the upper body section and has been carried out in many cases in the industry. The excavation industry performs RULA assessment with Digital Human Modeling by CATIA [7]. Applied improvement tools Iron pan reduces RULA scores in excavation [8]. The garment industry carries out RULA assessment with Digital Human Modeling by CATIA [9]. Workstation design was designed, and RULA was analyzed at street food in India [10]. Tools re-design was applied, and RULA was analyzed at water fetchers [11]. Workstation design was designed, and RULA was analyzed at the manufacturing workstation [12]. Tools re-design was applied, and RULA was analyzed at the ablution system [13]. Workstation design was designed, and RULA was analyzed by DHM at the manual assembly manufacturing workstation [14]. DHM, RULA with CATIA software was carried out in small-scale cast iron foundries in India [15][16]. Improvement on Tool's wheels chairs and RULA analysis are carried out [17]. DHM, RULA with CATIA software was carried out in chemical companies [18].

The literature review shows that almost all industries use RULA as assessment tools and CATIA as digital human modeling in each case. The significant contribution of this article was digital human modeling for the new workstation to obtain good RULA Scores in the horticulture field. This journal aims to explore the application of computer-aided ergonomic analysis and digital human modeling techniques in optimizing the workstations of farmers in water spinach plantations.

2. METHODS

2.1 Digital Modeling Human

The actual modeling of farmers was converted to digital human modeling (DHM) by CATIA. Before visual recording, farmers' body was measured by measuring instrument. A camera took a visual recording of every step of activity and then converted it to DHM. to ensure similarities in DHM and basic modeling of farmers, the visual recording was detailed. It measured the angle of the limb part and the range length, as shown in Fig.2.

Figure 2. Digital Human Modeling (DHM**)**

2.2 Work Environment Model

In this work environment model, the old workstation, especially at the ball valve, was replaced by the new workstation, a modified ball valve to motor operated valve (MOV). MOV was installed in two sections. Section one installed one MOV, whereas two MOV were in section two. MOV was designed to be controlled by an Android phone; thus, it can be regulated by farmers' phones. It made it an easy task for farmers, which, before modification, farmers should manually regulate, as shown in Fig.3.

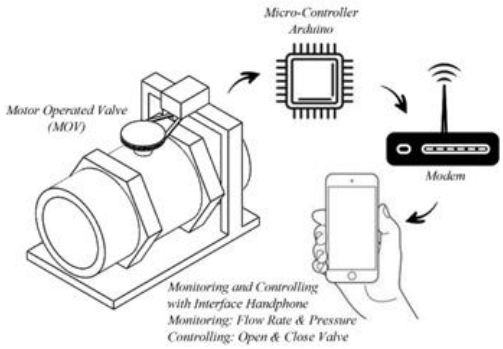

Figure 3. Automation Motor Operated Valve process

2.3 Task Simulation

The work movement in planting water spinach plants is described into several elements of movement. The decomposition of movement elements is carried out before and after repair. Each element of movement is traced using a camera, and posture is measured using measuring instruments. Each element of movement that has been measured is then converted into DHM, and RULA analysis is carried out using the software. The results of this RULA will see which parts of the body experience excessive movement, so it will be a suggestion for improvement.

2.4 Body Posture Analysis

Rapid Upper Limb Assessment (RULA) was carried out to analyze risk factors upper limb section of work-related musculoskeletal disorders (MSDs) [3]. The RULA score must be compared to body posture farmers using an old ball and motor-operated valve (MOV). Every DHM must convert to RULA, which can measure muscle constraint divided into four levels of MSDs Risk Level such as 1-2 is negligible, 3-4 is a lower risk, 5-6 is medium risk, and 7 is a high risk, as shown in Fig.4.

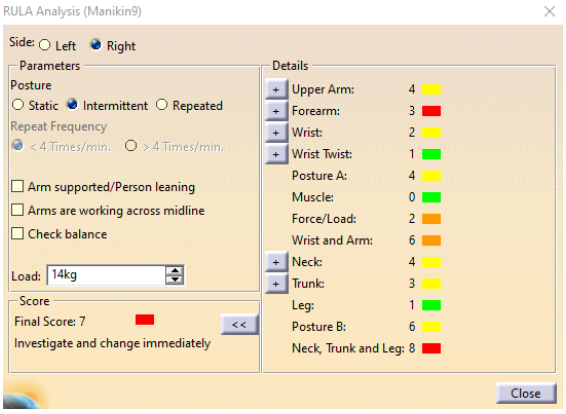

Figure 4. RULA Analysis result

2.5 Ergonomic Analysis

The ergonomic analysis is done by looking at computer-aided ergonomic RULA analysis data. Each movement element will be analyzed more detail on body posture, including the upper arm, forearm, wrist twist, posture A, muscle, Force load, Wrist and arm, neck, trunk, leg, posture B, neck, trunk and leg. These details each have a score and are accumulated into the final score. All movement elements that have been analyzed and have a total score will be considered for improvement.

3. RESULTS AND DISCUSSION

3.1 Body Posture Analysis

RULA analysis of farmer watering plants using CATIA has been conducted and completed. Figures 2 and 4 show that one of many activities to process digital human modeling was converted to RULA Analysis before improvement condition. Moreover, figure 5 shows that the processing of digital human modeling was converted to RULA analysis after improvement conditions.

Figure 5. Digital Human Modeling (DHM**)** After

Table 1 Shows some findings in the state before the repair, including there are 3 movement elements, Opening Valve II, Closing Valve I, and Closing Valve II, which has a score of 7, meaning that the movement element must be repaired immediately for these considerations improvements are made so that after the repair the movement elements are eliminated.

Table 1 shows collecting scores obtained from various posture bodies before and after the improvement water spinach plantation. There were 12 body posture positions in 2 conditions RULA Scores, and the Maximum RULA score was seven at opening valve II, Closing Valve I, and Closing Valve II body posture position before improvement. Moreover, after improving the body posture position of opening valve II, Closing Valve I, and Closing Valve II, the score was 2. The average RULA scores before and after improvement were 4, which means Risk, and 1, negligible. It shows that the improvement succeeds in reducing the score of RULA by 2. The percentage score reduction of the RULA Score comparing the old and new workstations is 75%, given below [19].

$$\%\, Value\ Reduction = \frac{ASI - ASN}{ASI}\ x\ 100 \quad (1)$$

Where:
ASI = Average Initial RULA Scores
ASN = Average New RULA Scores

3.2 Statistical Analysis of RULA Score

Post-Hoc analysis RULA scores using t-Test: Paired Two Sample for Means methods. Based on Table 2 shown, Statistically significant results when comparisons were made using the t-Test: Paired Two Sample for Means methods. Pearson correlation was 0,9, which means that the correlation between before and after improvement is excellent enough because it is close to 1.

Table 1. RULA Score of Farmers watering plantation.

Body Posture Position	Final RULA Scores	
	Before Improvement	After Improvement
Walking to Valve II	2	0
Standing in Front of The Valve II	2	0
Opening Valve II	7	2
Standing after Opening Valve II	4	0
Walking to Valve I	2	0
Standing in Front of The Valve I	2	0
Closing Valve I	7	2
Standing after Opening Valve I	4	0
Walking to Valve II	2	0
Standing in Front of The Valve II	3	0
Closing Valve II	7	2
Standing after Opening Valve II	4	0
Average Total Scores	***4***	***1***

P(T<=t) one-tail and P(T<=t) two-tail was 0,0000012 and 0,0000024, which was smaller than 5%, and it meant that the different tests before and after improvement were significantly different. The t Critical one-tail and t Critical two-tail were 1,8 and 2,2, whereas the t stat has 8,9. The result is significantly different at t stat > t Critical one-tail and t Critical two-tail.

Table 2. Post-Hoc Analysis RULA Scores

Indicators	*Before Improvement*	*After Improvement*
Mean	4	0,5
Variance	4,3	0,8
Observations	12	12
Pearson Correlation	0,9	
Hypothesized Mean Difference	0	

df	11
t Stat	8,9
P(T<=t) one-tail	0,0000012
t Critical one-tail	1,8
P(T<=t) two-tail	0,0000024
t Critical two-tail	2,2

4. CONCLUSION

DMH to ergonomic analysis was successful clearly in helping RULA methods numerically. The work-related musculoskeletal disorders (MSDs) among farmers of watering plants before improvement have been RULA analysis was 4. It meant that there was a need to investigate and improve immediately. After modifying the ball valve to MOV, RULA analysis reduced the score to 1. They compared before and after improvement results in a percentage reduction in RULA Scores of 75%.

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