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Application of Rula and Catia V5 in Designing Ergonomic Tools For Cleaning Staff Performance Improvement

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ABSTRACT

Cleaning staff play an important role in maintaining environmental cleanliness, but most still use simple equipment with non-ergonomic working postures. This condition risks causing musculoskeletal disorders (MSDs) and reducing work productivity. This study aims to design an ergonomically-based tool for collecting trash and leaves that can improve the comfort and efficiency of sanitation workers. The method used is Rapid Upper Limb Assessment (RULA) to measure the level of work posture risk, combined with design analysis us-ing CATIA V5 software tailored to user anthropometric data. The results showed that the RULA score before using the tool was at level 5, indicating the need for immediate improvement. After design and simulation, the RULA score decreased to level 2, meaning that the risk of injury was significantly reduced. These findings prove that ergonomically-based tool design can reduce physical workload, minimize the risk of MSDs, and improve the work efficiency of cleaning staff. This research contributes to the development of ergonomic cleaning equipment innovations and can be used as a reference for the design of similar work tools in other sectors.

Keywords: Design Tools, RULA, CATIA V5, Ergonomic

INTRODUCTION

Environmental cleanliness is one of the important factors in supporting the safety, health, and productivity of the community [1]. A clean environment not only reflects the quality of governance, but also contributes to disease prevention and improved quality of life. To achieve this, the role of sanitation workers is vital because they are directly responsible for maintaining the cleanliness of public areas and institutions [2]. However, this work is often carried out in conditions that are not ergonomic, which can potentially cause long-term occupational health problems [3].

Based on observations, many cleaning staff work with simple equipment and postures that do not meet ergonomic standards, such as bending over, lowering their necks, or performing repetitive movements [4]. These conditions cause rapid fatigue, decreased productivity, and the emergence of musculoskeletal disorders (MSDs). Work tools such as brooms or traditional trash collectors are often not adjusted to the anthropometric measurements of the user, thereby increasing the risk of injury [5].

A number of previous studies have highlighted the application of ergonomics in manual work activities. For example, a study shows that the application of ergonomics can reduce the risk of MSDs in the agricultural sector, while studies by prove the importance of improving tool design to reduce RULA risk scores. However, the majority of studies still focus on the industrial and agricultural sectors, while studies related to the design of ergonomic tools specifically for cleaning staff in public spaces, such as roads or campuses, are still very limited. This gap is the basis for the need for this study.

The main problem faced by cleaning workers is the use of non-ergonomic tools, which causes them to bend and stoop for long periods of time [6]. This results in high RULA risk scores, which means that immediate improvements are needed [7]. Thus, there is a need for innovations in the design of waste transport and collection tools that can reduce the risk of injury, improve comfort, and at the same time support the work efficiency of cleaning workers [8].

This study aims to design a tool for collecting trash and leaves by considering ergonomic aspects using the RULA method and modeling through CATIA V5 software. This design is expected to reduce the RULA risk score, while proving that the application of an ergonomic approach to cleaning tools can increase efficiency and reduce the potential for MSDs. The novelty of this research lies in the application of a special ergonomic design for cleaning staff with a multifunctional tool that is more suited to the anthropometric dimensions of the user.

The results of this study are expected to provide theoretical and practical contributions. Theoretically, this study expands the study of ergonomics in the field of environmental hygiene, which has previously been rarely discussed. Practically, this research produces a prototype tool that can be used to improve the comfort, safety, and productivity of cleaning staff, while also supporting the creation of a cleaner and healthier environment. Thus, this research has the potential to become a reference for the development of ergonomic cleaning equipment design in the future.

METHOD

Data Collection Techniques

a. Interview

The activity was carried out by interviewing cleaners who worked on an East Jakarta street. The discourse was carried out to find out the subject's personal data as well as the officer's body complaints and other data related to musculoskeletal disorders in the cleaner [9]. Data collection was carried out by taking pictures of the posture of the janitor while working [10].

b. Body Anthropometric Data

Anthropometric data is needed because the design is carried out regarding the dimensions of the human body [11]. The anthropometric data needed in the design are as follows:

1) Standing elbow height (TSB)
2) Shoulder width (LB)
3) Maximum grip diameter (DGmak)

Data Processing Techniques

After the required body anthropometric data is collected, data processing is carried out. The stages of anthropometric data processing are as follows [12]:

a. Normality Test

In this study, the data normality test was used SPSS software for Windows 20. By looking at the chi table and chi square [13], [14], [15].

b. Uniformity Test

In this study, the uniformity test was carried out by looking at the control map processed through the excel program. Where using an accuracy level of 5% and a confidence level of 95% to determine the values of BKA (upper control limit) and BKB (lower control limit). This means that at least 95 out of 100 data taken have irregularities of no more than 5%.

c. Sufficiency Test

The data sufficiency test is used to find out whether the data taken is sufficient or not. The data adequacy test in this study used an accuracy level of 5% and a confidence level of 95%. This means that at least 95 out of 100 data retrieved have no more than 5% deviation.

d. Percentile Determination

The use of percentiles in planning greatly influences the design of the tools to be designed. Whether or not a designed tool can be used by 95% of its users is determined by the percentile used by the designer. The percentile calculation in this study used an accuracy level of 5% and a confidence level of 95%.

1. Drafting the Concept

After the data is collected, the product concept is compiled, the product concept is an overview or estimate of the technology, working principle and form of the product to be developed. In this study, the product concept was compiled based on anthropometric data.

2. Design Visualization

Design visualization in this study is the stage of describing and applying product concepts in the form of 2-dimensional drawings, 3-dimensional drawings and real products.

3. Concept Testing

Product concept testing is carried out to find out if the user's needs have been met. If user feedback is poor, the development project may be stopped or some initial activities may be repeated when needed. In this study, the concept test carried out by the researcher was by trying a garbage collector tool on the streets of East Jakarta. If the waste collection equipment tested on the cleaning staff is successful, then this research is successful. And if the product fails, then a percentile recalculation will be done to design the tool [16].

4. Setting Final Specifications

If the product made is in accordance with expectations, namely in accordance with the needs of the user, then the final specifications of the product concept are determined [17], [18], [19], [20].

RESULTS

Measuring Rapid Upper Limb Assessment (RULA) Using CATIA Software

Measuring the working posture of cleaning service officers using the corners of the posture when doing work, then the risk of injury is calculated using the RULA method. The results obtained according to the final score of the RULA are that the work posture of cleaning service officers requires handling or preventive measures and changes.

A. Standing Elbow Height

Standing Elbow Anthropometry or abbreviated as TSB is the vertical distance from the floor to the meeting point between the upper arm and forearm. The subject stands upright with both hands hanging reasonably. The following are the 5th, 50th, 95th percentile and standard deviation from TSB anthropometry.

Table 1. Standing Elbow Height Anthropometry

Anthropometry	5th	50th	95th	SD
Standing Elbow Height	73.13	95.65	118.17	13.69

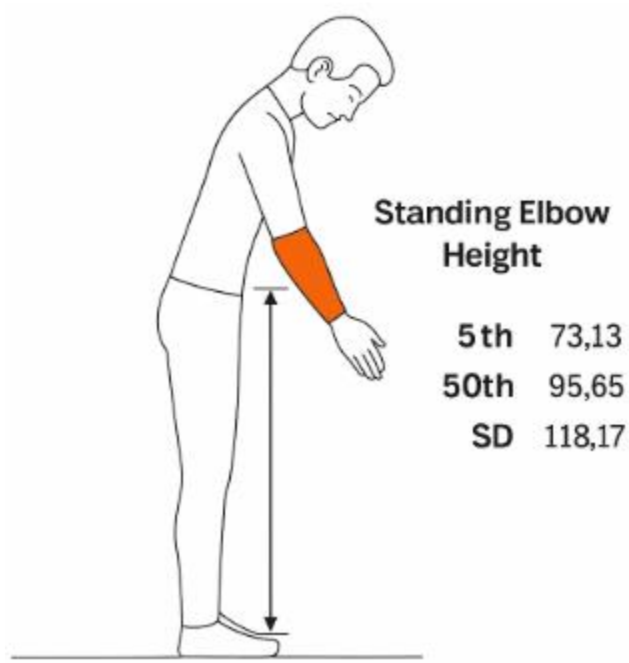

Figure 1. Standing Elbow Posture

The results of standing elbow height measurements show the mean value, standard deviation, and range at the 5th, 50th, and 95th percentiles. Based on the table, the standing elbow height at the 5th percentile is 73.13 cm, at the 50th percentile is 95.65 cm, and at the 95th percentile is 118.17 cm with a standard deviation of 13.69 cm.

The image displayed shows the standing elbow posture on the human body, highlighting the anatomical position of the elbow when standing upright. This information is important for ergonomic design applications, such as the design of work tables or tools that adjust to the user's elbow height to improve comfort and reduce the risk of muscle and skeletal injuries. This percentile data is also very useful for ensuring that products or work environments are accessible and comfortable to use for the majority of the population, from shorter to taller individuals.

B. Shoulder Width

Anthropometric measurement of shoulder width is performed by measuring the length of the left shoulder tip to the right shoulder tip, the subject is in a normal position. The following are the 5th, 50th, 95th percentiles as well as the standard deviation from shoulder width anthropometry.

Table 2. Shoulder Width Anthropometry

Anthropometry	5th	50th	95th	SD

Shoulder Width	26.35	38.75	5.16	7.54

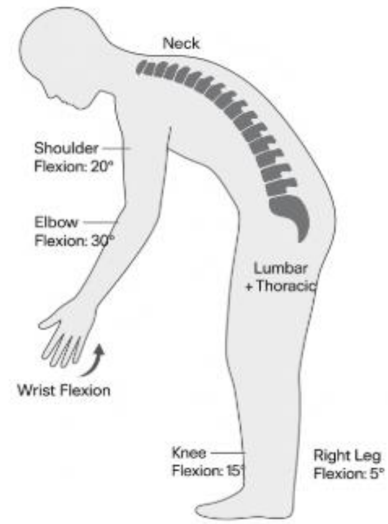

Figure 2. Shoulder width

Table 2 presents anthropometric data on shoulder width at the 5th, 50th, and 95th percentiles, as well as standard deviation values. The 5th percentile value is recorded at 26.35 cm, the 50th percentile at 38.75 cm, and the 95th percentile at 51.6 cm, with a standard deviation of 7.54 cm. These data indicate that there is a significant variation in the shoulder width of the population, which is important to consider in the design of ergonomic products or work environments.

A posture with 25° thoracic spine flexion and 15° neck flexion indicates a biomechanical risk to the musculoskeletal system. Based on ergonomic standards (e.g., OWAS, RULA, or REBA), the combination of flexion in the neck, back, and knees can increase the ergonomic risk score, requiring interventions such as the design of work aids, desk height adjustments, or the use of lifting devices.

C. Forearm Length

The length of the forearm is determined by taking measurements starting from the elbow meeting the upper arm and forearm, to the palm. With the subject's position in normal circumstances. The following are the 5th, 50th, 95th percentiles as well as the standard deviation from forearm length anthropometry.

Table 3. Anthropometry of forearm length

Anthropometry	5th	50th	95th	SD
Forearm Length	26.66	40.53	54.4	8.43

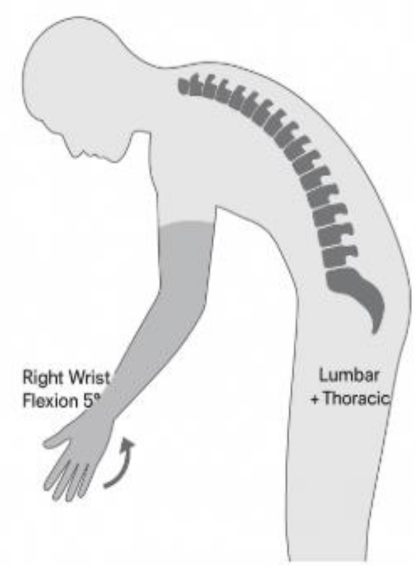

Figure 3. Forearm Length

Tool Design

Tools designed to help cleaning officers in carrying out their duties are in the form of tool innovations that can change the work system of officers at work. The design of this tool can improve the posture of cleaning service personnel and reduce movement movements that can cause problems and injuries to the skeletal muscle system. The design of the tool has been innovated so that it is able to have more functions compared to the equipment used before. The design of this garbage collector has two main functions, namely being able to capture the garbage that passes by, and collecting it directly in one place in the form of a portable trash can box directly on the tool.

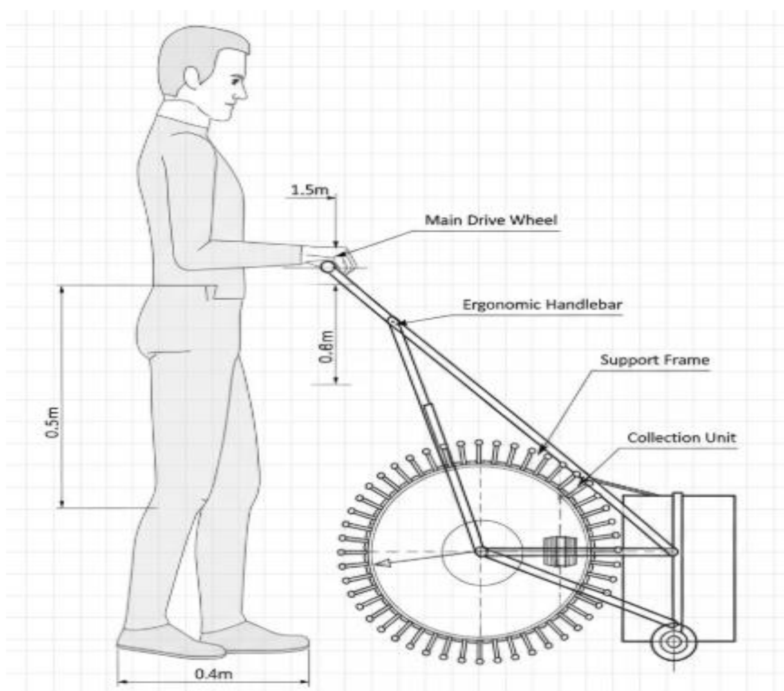

Figure 4. Tool Design

This tool is a mechanical device with a main drive wheel system, support frame, and collection unit that is designed to assist with field work. The design focuses on user comfort with an ergonomic handlebar that is adjusted to the average human height (1.5 m) and optimal grip distance (0.8 m from the wheel surface). With this approach, ergonomic problems and operator fatigue can be minimized, thereby increasing work productivity. The selection of large wheel diameters with additional hooks around them also demonstrates an effort to optimize the efficiency of material collection on the ground surface.

This design also addresses the need for an appropriate tool for transporting environmental waste. This tool is designed to be energy efficient and environmentally friendly for outdoor material collection activities. The integration of a lightweight mechanical design with an integrated collection system highlights efforts to solve problems previously faced by users of conventional tools, namely non-ergonomic posture, limited capacity, and dependence on fuel-powered machines. Thus, this innovation not only contributes technically but is also relevant to sustainability issues and improvements in workplace safety and comfort, aligning with the urgency of current research in industrial design and ergonomic engineering.

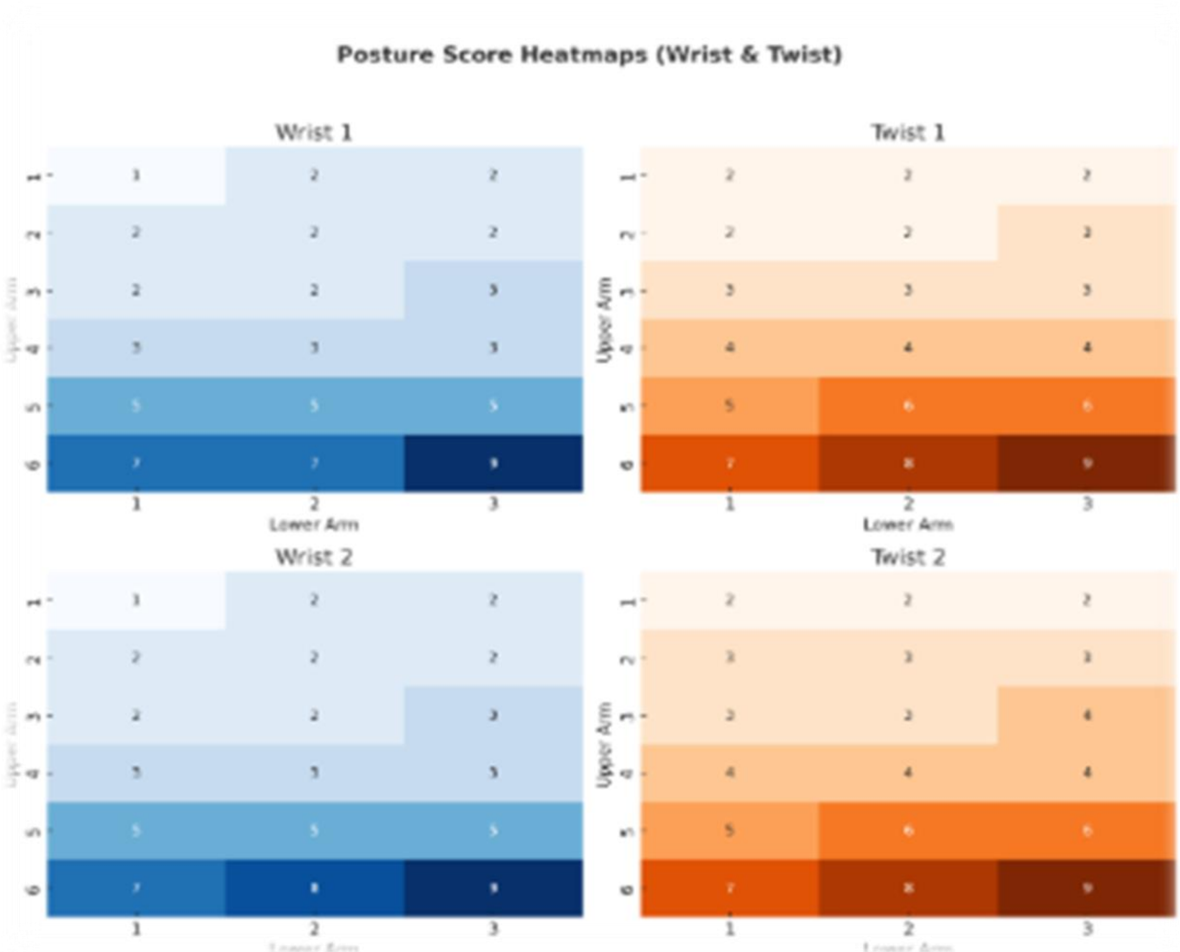

Figure 5. Posture Score

Figure 5 shows a posture score heatmap that illustrates the distribution of scores based on wrist position (Wrist 1 and Wrist 2) and rotation (Twist 1 and Twist 2), with the upper axis variable being the upper arm position and the lower axis variable being the lower arm position. Each box on the heatmap represents the posture score for a specific combination of upper arm and lower arm positions.

In the Wrist 1 heatmap, it can be seen that the posture score is relatively lower in the lower upper and lower arm positions (values 1 and 2), with a significant increase in the posture score when the upper and lower arm positions reach values 5 and 6, indicating a potential risk of worse posture in these positions. A similar pattern is seen in Wrist 2, but with a higher concentration of scores in the range of 5 and 6 for the upper arm, indicating that changes in the upper arm position affect the increase in posture scores in the second wrist.

In Twist 1 and Twist 2, the score distribution tends to show consistently higher values, particularly in the higher upper and lower arm positions (values 5 and 6), indicating an increased risk of posture in wrist rotation. The highest score, reaching a value of 9, is seen in the lower arm 3 and upper arm 6 positions in Twist 2, indicating a significant potential ergonomic risk in that combination of positions.

Overall, this heatmap shows that the position of the upper and lower arms plays an important role in determining the risk level of posture, both at the wrist and in rotation, with higher risks concentrated in higher arm positions and more extreme combinations of rotation. These findings can be used to identify potentially risky work postures and design more targeted ergonomic interventions.

DISCUSSION

The final score for the elements of the cleaning service officer's activities is 5, based on this score, the risk level of the activity is in the category of requiring follow-up actions and necessary changes in posture. Posture that bends over while working by cleaning service officers can be caused by several things, including a habit that has been done for a long time. Getting used to postures that are unnatural and can be a factor causing skeletal muscle system problems is not good. According to research [21] the application of ergonomics to work tools has an impact on a more natural working posture. This aims to avoid the occurrence of musculoskeletal complaints in workers. In his research, it was explained that poor working posture due to poor lifting and manual handling of agriculture causes musculoskeletal disorders (MSDs) [22]. This disorder has symptoms including pain in the lower and upper back, shoulders, ankles, knees, elbows, neck, wrists, and hands. Research Results (Montororing) Design of work aids to overcome work problems that occur so that they can support the improvement of work from the operator [23]. Because with good working conditions and a level of fatigue that can be controlled, humans as workers will achieve high productivity. Based on this description, this study applies ergonomics to the design of work aids [24].

The problem that occurs that causes the position of the body to be bent is the proximity of the object to be seen and is below. So that the body responds to bend over, as an effort to be able to reach the object to be seen [25]. and also inadequate equipment such as a short skewer broom, causing the body to bend to reach the object to be swept away. The results of the research [26] were obtained that the activity did not get a change in posture because it scored 7 at the moderate level in the calculation of entering category 2 in the calculation of pushing goods and arranging products entered a very high level in the calculation with a score of 11 and entered categories 3 and 4 in the calculation. In the activity of lifting goods, pushing goods and arranging products will get an improvement in posture which will be assisted by work tools. Another research result that strengthens the argument of tool design is [27] high risk of working posture gets a final score of 7 high risk levels, so improvements are needed to reduce the occurrence of MSDs by making changes in various work postures or by providing work aids in the form of work desks, so that workers can carry out their work activities safely and comfortably. A comparison of posture before and after the design of the tool shows a significant difference [28]. The factors that cause injuries and skeletal muscle system complaints, namely poor posture before changes with the design of the tool, are no longer present in the posture after the design of the tool. A hunched posture and a bent neck are no longer present in the posture after the design of the tool. Because before designing the tool, the officer saw the object down and close to his body [29]. However, after the design of the tool, the officer no longer sees the object nearby, but the garbage that will be taken by the officer will see it in front of the design tool, which makes the body no longer need to bend and the neck bends excessively. The design of the tool also allows the user not to perform repetitive movements. The user only needs to hold the tool and encourage it to pick up the garbage and leaves. The garbage and leaves will be trapped on the spine wheel, and then go to the net separating the spine wheel, then to the garbage storage box in front of it. So that users no longer need to engage in repetitive activities that can cause injuries and complaints to the skeletal muscular system [30].

CONCLUSION

This study successfully designed an ergonomic tool for collecting trash and leaves to improve the performance of sanitation workers. The results of work posture measurements using the RULA method showed significant improvements, where the initial score of 5, which was classified as high risk, was successfully reduced to a score of 2 after using the new tool design. This proves that the application of anthropometry and CATIA V5 simulation in the design process can produce tools that are safer and more comfortable to use.

The design of this tool makes a real contribution to efforts to reduce the risk of musculoskeletal complaints and improve the work efficiency of cleaning staff. In practical terms, this research can be used as a reference for institutions or cleaning service providers to provide equipment that complies with ergonomic principles. Academically, this research expands the ergonomics literature in the context of environmental hygiene, which has previously been rarely studied in depth.

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