International Research Journal of Engineering, IT & Scientific Research
Available online at https://sloap.org/journals/index.php/irjeis/
Vol. 11 No. 4, July 2025, pages: 105-113
ISSN: 2454-2261
https://doi.org/10.21744/irjeis.v11n4.2548

Integration of Ergonomic Principles in the Design and Construction of Car Wheel Polishing Tools to Improve Operator Performance

I Gede Santosa [a]
M. Yusuf [b]

Article history:

Submitted: 09 May 2025
Revised: 18 June 2025
Accepted: 27 July 2025

Keywords:

anthropometry;
ergonomics;
wheel polishing tools;
work efficiency;
working posture;

Abstract

The use of manual tools in the process of polishing car wheels is still widely found in a variety workshops, which has an impact on low work efficiency and high physical load on operators. This research aims to design and build ergonomics-based car wheel polishing tools to improve operator efficiency and work comfort. The method used is design and construction with an ergonomic approach, starting from identifying user needs, collecting anthropometric data, to testing the functionality of the tool. The design of the tool was adjusted to the anthropometric data of 10 workshop operator respondents, resulting in a tool with dimensions of 100 cm × 70 cm × 120 cm. The evaluation was carried out by comparing the polishing performance manually and using tools in terms of working time, fatigue level (Borg CR-10), and work posture (RULA). The results showed that the average polishing time decreased from 65 minutes (manual) to 12.3 minutes (using tools), with a time efficiency of 80.8%. The fatigue score decreased from 7.6 to 2.9, and the RULA score showed a decrease in ergonomic risk from high to moderate-low. The paired t-test showed a statistically significant difference (p<0.05) across the parameters tested. The integration of ergonomic principles in tool design has proven to be effective in optimizing work productivity, improving work posture, and reducing operator fatigue. This research makes an important contribution to the development of work tools that are safer, more efficient, and in accordance with human needs, especially in the work environment of small and medium-scale automotive workshops.

Corresponding author:
M. Yusuf,
Department of Mechanical Engineering,
Politeknik Negeri Bali, Badung, Indonesia.
Email address: yusuf@pnb.ac.id

[a] Department of Mechanical Engineering, Politeknik Negeri Bali, Badung, Indonesia
[b] Department of Mechanical Engineering, Politeknik Negeri Bali, Badung, Indonesia

1 Introduction

Car variety workshops are one of the automotive service sectors that are experiencing rapid growth in line with the increase in private vehicle ownership and public interest in vehicle modifications. One of the services that is in great demand is polishing car wheels**,** both for aesthetic purposes and routine maintenance. However, until now, the process of polishing wheels in many workshops is still done manually using a drill or hand grinder. This method is not only time-consuming but also requires a lot of physical effort and has the potential to cause fatigue and ergonomic risks for operators (Biradar et al., 2024; Kaur, 2022; Chen & Ou, 2020).

Problems that often arise in the manual polishing process include low time efficiency, uneven polishing results, and high operator workload**.** In addition, the lack of attention to ergonomic work tool design leads to a high risk of musculoskeletal complaints, unnatural working postures, and decreased operator productivity in the long term (Choobineh et al., 2021; Elbert et al., 2018; Taib et al., 2021). Although there have been several studies on the design and construction of wheel polishing tools (Santosa et al., 2021; Sudana & Yusuf, 2024). Most of them have only focused on the mechanical and functional aspects of the tool without considering the comfort, safety, and adaptability of the tool to human posture.

Based on these conditions, the research gap that needs to be addressed is the lack of an integrated approach between the design engineering of wheel polishing tools and the principles of ergonomics and anthropometry that can improve the performance and comfort of operators. The integration of ergonomic principles in tool design is essential to reduce physical workload, improve work posture, and significantly increase work efficiency and productivity (Yusuf et al., 2025; Santosa & Yusuf, 2023; Suarbawa et al., 2024).

The novelty of this research lies in the incorporation of technical (mechanical) and ergonomic aspects in the design of car wheel polishing tools, especially by adjusting the anthropometric size of the operator's body. This research also emphasizes the evaluation of tool performance through the measurement of working time efficiency, perception of comfort, and ease of use by operators**,** resulting in tools that are not only technically functional but also adaptive to human needs in the context of long-term work.

This study aims to (a) design and build a car wheel polishing tool with a maximum ring of 22 inches that integrates the principles of ergonomics and user anthropometry**,** (b) analyze the work efficiency and performance of the operator before and after the use of the designed tool, (c) improve the comfort and safety of the operator's work through the design of the tool following the posture and work habits, (d) provide alternative solutions workshop work tools that are more effective, efficient, and ergonomic to support work productivity in the field of automotive maintenance.

This research is expected to make a practical contribution in reducing work fatigue, improving time efficiency, and minimizing ergonomic risks in workshop operators, as well as becoming an early model in the application of ergonomic design in MSME-scale automotive equipment. In addition, this approach can be adopted in the development of other work tools that have not considered human factors adequately in the design process (Santosa, 2022).

2 Materials and Methods

Research Approach

This research uses a design approach with the integration of the principles of work ergonomics and user anthropometry. This method was chosen to produce a car wheel polishing tool that is not only technically functional but also follows the physical characteristics and working comfort of the operator, to improve work efficiency and productivity.

Anthropometric Data Collection

Anthropometric data were collected from 10 male workshop operator respondents who were targeted tool users.
Measured body dimensions include:

a) Height
b) Elbow height sits and stand
c) Arm span

d) Forearm length
e) Horizontal and vertical reach

This data is used to determine the optimal dimensions of the tool, such as table height, control position, and working range area.

Tool Design

The design considers the principles of anthropometry, biomechanics, and occupational safety. The design of this tool has the main components, including:
a) Framework
b) Wheel-rotating motor
c) Polished eye drive dynamo
d) Forward-backward and up-and-down control system

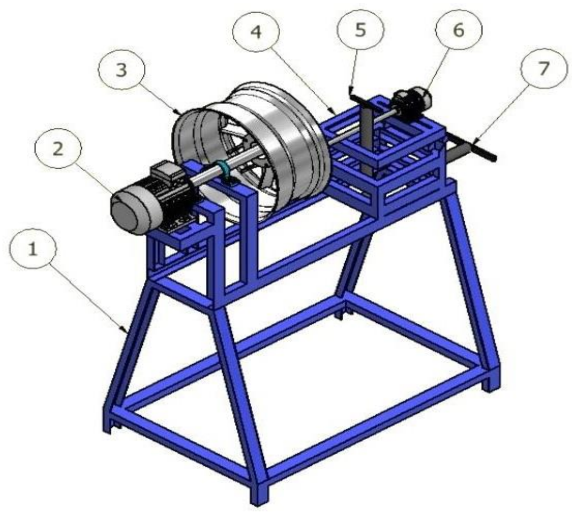

Figure 1. Car Wheel Polishing Tool Design Model

Information:
1. Skeleton
2. Electric motors
3. Rim
4. Polished dynamo regulating frame
5. Up and down controller polish the eye
6. Dynamo poles
7. Forward and backward adjustment polish the eye

The tool is realized according to the design of the simulation results. The manufacturing process includes material cutting, mechanical assembly, electric motor installation, and structural finishing.

Tool Testing and Performance Evaluation

The test was conducted experimentally to compare the two conditions:
a) Manual polishing of wheels
b) Polishing of the wheels using the designed tools

Measured parameters:
a) Polishing time (with stopwatch)

b) Operator's level of work fatigue (via the Borg CR-10 Scale questionnaire)
c) Perception of comfort and ease of work (via the Likert questionnaire)
d) Work posture was evaluated using the Rapid Upper Limb Assessment (RULA) method
e) Production yield and productivity

Data Analysis

The test result data was analyzed quantitatively using:
a) Average and efficiency of working time (%)
b) Comparison of fatigue and comfort scores before and after use of the appliance
c) Analysis of work posture ergonomics based on RULA scores

A tool design is said to be successful when:
a) It can save ≥ 50% working time compared to manual methods
b) Gave a minimum comfort score of the "comfortable" category to ≥ 80% of respondents
c) Downgrading the RULA score to a low or medium risk category

3 Results and Discussions

3.1 Results

a. Tool Design Results
The results of the design and construction of ergonomic-based car wheel polishing tools were successfully realized according to the design. The dimensions of the tool were adjusted to the anthropometric data of 10 respondents, namely 100 cm long, 70 cm wide, and 120 cm working height, which allowed the operator to work both in a standing and sitting position. The main components of the tool consist of:
1) Main frame, designed with height to standing elbow height (±110–120 cm)
2) Wheel-drive electric motor, which is capable of rotating the wheels at a constant speed
3) Polished eye-drive dynamo, moving in the opposite direction to the wheels
4) Vertical and horizontal adjustment system of the polished eye, allowing position adjustment according to the surface of the wheel

This tool pays attention to the principles of optimal working range, posture balance, and ease of operation to minimize the risk of fatigue.

Figure 3. Design results and operator work posture

b. Polishing Time Efficiency
Time testing is performed to compare manual methods with tools. The results of the analysis of working time from 10 respondents are as follows:

Table 1
Manual Polishing Time vs Using Tools

	Average time (minutes)	SD	t	p
Manual	65,0	2,94	39,45	0,000
Using the tool	12,3	0,95		

Statistical tests were performed using a paired t-test (two tails) with a significance level of $\alpha = 0.05$ to see a significant difference between manual and tool working time. There was a very significant difference between manual polishing time and using the tool **(**$p < 0.05$**)**, proving that the tool is able to significantly improve the operator's work efficiency.

The tool can save working time from 65 minutes to 12.3 minutes, or decrease by 81.1%, which means the work process becomes much more efficient. This shows that tool design successfully eliminates repetitive and unproductive movements, two aspects that are often emphasized in the principles of work ergonomics (Bhatia et al., 2024; Shin et al., 2021; Yusuf, Suarbawa, & Santiana, 2025).

c. Work Posture Analysis (RULA)

Work posture analysis using the RULA (Rapid Upper Limb Assessment) method showed the following results:

Table 2
Results of RULA analysis

Method	Skor RULA	Category Risk
Manual	6–7	High (immediate intervention)
With Tools	3–4	Medium–Low (need monitoring)

d. Operator Performance Evaluation

Operator performance evaluation is seen based on comfort, fatigue level, production output and work productivity. Perception of Comfort was measured using a questionnaire with 5 Likert scales. Questionnaire completions by respondents using the Likert scale (1–5) showed the following results:

1) Average work position comfort: 4.3 (*comfort* category)
2) Ease of use of the tool: 4.5
3) Vibration and noise level of the tool: 3.9 (good enough)

Meanwhile, Work Fatigue was measured using the Borg CR-10 Scale questionnaire. The measurement results are as follows.

Table 3
Operator fatigue measurement results

	Average fatigue score	SD	t	p
Manual	7,6	0,69	24,67	0,000
Using the tool	2,9	0,74		

Based on the results of the analysis, the use of the tool provides a statistically significant reduction in fatigue. The appliance is proven to be ergonomic and capable of reducing the physical workload.

e. Performance based on production output and work productivity

Performance based on production output and work productivity can be seen in the following table.

Table 4
Comparison of Production Output and Work Productivity

Method	Number of Wheels per 2 Hours	Productivity (units/hour)
Manual	2 Rim	1.0 units/hour
With Tools	10 Rim	5.0 units/hour

Information:
1 unit = 1 piece of polished wheel
Calculation based on average actual polishing time

3.2 Discussion

The results of the study show that the use of ergonomics-based car wheel polishing tools is able to significantly increase operator work efficiency. The average polishing time that was previously up to 65 minutes with the manual method can be cut to just 12.3 minutes after using the tool, resulting in an efficiency of 80.8%. Statistical analysis through paired t-tests showed *a p* < value of 0.05, which indicates that the difference in working time between the two methods is statistically significant. These findings are in line with the statement of Budiyanto (Budiyanto & Yusuf, 2020) that the design of tools that suit the needs and workflows of operators can speed up the production process and increase work output. Thus, the design and construction of this tool not only increases the speed of work but also provides real benefits in the optimization of working time in the workshop environment.

In addition to improved time efficiency, the results of the ergonomics evaluation showed that the operator's work fatigue rate was significantly reduced. The fatigue score based on the Borg CR-10 Scale decreased from an average of 7.6 (severe category) to 2.9 (mild category), which was also supported by statistical test results showing $p < 0.05$. This decrease indicates that the designed tool can reduce the static and repetitive physical workload, which in previous manual work was a major factor in causing fatigue. This is reinforced by the research that stated that physical loads can be reduced through the design of a tool that pays attention to neutral body position, range of motion, and ease of operation (Biradar et al., 2024; Sudiajeng et al., 2023; Yusuf et al., 2025). With a more stable working posture and flexible working position (can be sitting or standing), the operator becomes more comfortable and does not get tired easily while working.

Furthermore, the evaluation of the working posture using the RULA method showed that the use of this ergonomic tool successfully reduced the risk of musculoskeletal disorders (MSDs). The RULA score dropped from a high-risk level (6–7) to a moderate to low risk level (3–4) when using the tool. This decrease shows that anthropometry-based tool designs have managed to accommodate the operator's body dimensions proportionally. The increase in production output and productivity is evident. The operator's work productivity increased from 1 unit per working hour to 5 units, or an increase of 400%.

The implications of this posture improvement are particularly important, especially in repetitive work such as wheel polishing, which often causes strain on the shoulders, back, and wrists if done manually and repeatedly in a non-ideal position (Pistolesi et al., 2024; Santiana & Yusuf, 2020; Suarbawa et al., 2024; Yusuf et al., 2022). Therefore, the design of this tool is not only relevant in the context of productivity, but also contributes to long-term occupational safety and health, especially in the working environment of small and medium-scale workshops where there is still minimal application of ergonomics. Time efficiency, reduced fatigue, and increased comfort also lead to a significant increase in operator productivity. Operators can complete more units of work in less time, with a lighter workload. This study has limitations, namely the small number of research samples, so that further studies are needed, focusing on one type of work (wheel polishing), and sustainability tests have not been carried out in the long term (tool durability and cumulative fatigue).

4 Conclusion

Based on the results of the research and discussion, it can be concluded that:

a) The design and construction of car wheel polishing tools based on ergonomic principles has been successfully realized with a design that considers user anthropometric data. It has dimensions of 100 cm (length), 70 cm (width), and 120 cm (height), and allows operation in both sitting and standing positions.

b) The use of this wheel polishing tool significantly improves the work efficiency, with the average polishing time reduced from 65 minutes to 12.3 minutes, resulting in an efficiency of 80.8%. The results of the statistical test showed a significant difference in working time between manual and tool methods ($p < 0.05$).
c) In terms of ergonomics, this tool can reduce the level of operator work fatigue, with the Borg CR-10 score decreasing from 7.6 to 2.9. In addition, the RULA score also showed a decrease in the risk of musculoskeletal disorders from high to moderate–low levels.
d) Operator work comfort has increased, as evidenced by the results of the questionnaire, which showed a positive perception of ease of use, stability of working posture, and reduction of physical load. This shows that the integration of ergonomic principles in tool design has a real impact on the operator's performance and work safety.

It is recommended that the application of this tool is highly recommended for car variety workshops, especially MSMEs, as an alternative solution for increasing work productivity without neglecting the aspects of safety and work comfort. For further development, it is recommended that the tool be equipped with an automatic adjustment **system** on the polishing eye (up–down and forward–backward) in order to reduce manual intervention and minimize the load of repetitive movements. Further research can expand coverage with a larger number of respondents, as well as conduct long-term testing to assess the impact of the tool on the operator's work performance and health during repetitive or intensive work periods**.** Simple training is also needed for operators to understand how the tool works and maintain it independently, as well as to raise awareness of the importance of ergonomics in technical work in the informal sector.

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The author(s) have approved the final article.

Acknowledgments
I am/We are grateful to two anonymous reviewers for their valuable comments on the earlier version of this paper.

 ISSN: 2454-2261

References

Bhatia, V., Vaishya, R. O., Jain, A., Grover, V., Arora, S., Das, G., ... & Saluja, P. (2024). Identification of prevalence of musculoskeletal disorders and various risk factors in dentists. *Heliyon*, *10*(1).

Biradar, V. G., Hebbal, S. S., & Qutubuddin, S. M. (2024). Ergonomic Risk Identification and Postural Analysis in Electrical Transformers Manufacturing Company located in Southern India. *International Journal of Occupational Safety and Health*, *14*(2), 144-151.

Budiyanto, T., & Yusuf, M. (2020). Improvement of Wok Molding Station Increases Work Comfort and Productivity of the Workers. *Int. J. Psychosoc. Rehabil*, *24*(4), 8883-8892.

Chen, Y. L., & Ou, Y. S. (2020). A case study of Taiwanese custom-beverage workers for their musculoskeletal disorders symptoms and wrist movements during shaking task. *International Journal of Industrial Ergonomics*, *80*, 103018. https://doi.org/10.1016/j.ergon.2020.103018

Choobineh, A., Shakerian, M., Faraji, M., Modaresifar, H., Kiani, J., Hatami, M., ... & Kamali, G. (2021). A multilayered ergonomic intervention program on reducing musculoskeletal disorders in an industrial complex: A dynamic participatory approach. *International Journal of Industrial Ergonomics*, *86*, 103221. https://doi.org/10.1016/j.ergon.2021.103221

Elbert, K. K., Kroemer, H. B., & Hoffman, A. K. (2018). Designing to fit the moving body. In *Ergonomics: How to Design for Ease and Efficiency* (pp. 379-441). Academic.

Kaur, B. (2022). A Study : Working Conditions Of Small Scale Weaving Units. *International Journal of Mechanical Engineering*, *7*(1), 1375–1379.

Pistolesi, F., Baldassini, M., & Lazzerini, B. (2024). A human-centric system combining smartwatch and LiDAR data to assess the risk of musculoskeletal disorders and improve ergonomics of Industry 5.0 manufacturing workers. *Computers in Industry*, *155*, 104042. https://doi.org/10.1016/j.compind.2023.104042

Santiana, I. M. A., & Yusuf, M. (2020). Design of Arrangement of Working Time to Increase Productivity of the Workers by Using Flat Iron at Garment "A." *Logic: Jurnal Rancang Bangun Dan Teknologi*, *20*(1), 35–39.

Santosa, I. G. (2022). Developing a wood lathe machine with speed control and workers' anthropometry to increase the productivity of broom industry. *International Research Journal of Engineering, IT and Scientific Research*, *8*(4), 144–151. https://doi.org/10.21744/irjeis.v8n4.2156

Santosa, I. G., & Yusuf, M. (2023). Ergonomic Multifunctional Building Tool Design to Increase Work Productivity of Msmes Employees. *American Journal of Science, Engineering and Technology*, *8*(4), 189–193.

Santosa, I. G., Yusuf, M., Gunung, I. N., & Rimpung, I. K. (2021). Application of Forging Hammer to Increases Productivity of Balinesse Blacksmith. *Proceedings of the International Conference on Innovation in Science and Technology (ICIST 2020)*, *208*(Icist 2020), 195–199.

Shin, J. S., Seo, K., Oh, H. J., Lim, M., Kang, H. T., Jeong, K. S., ... & Oh, S. S. (2021). Relationship between job rotation and work-related low back pain: a cross-sectional study using data from the fifth Korean working conditions survey. *Annals of Occupational and Environmental Medicine*, *33*, e3.

Suarbawa, I., Yusuf, M., & Sudiajeng, L. (2024). Ergonomic Factors Which Affect the Work Productivity of Clove Flower Harvesters. *International Journal on Advanced Science, Engineering & Information Technology*, *14*(2).

Sudana, I. M., & Yusuf, M. (2024). Design of Ergonomic Flour Dough Mixer with Participatory Approach to Increase Work Productivity MSME Employees. *European Journal of Applied Science, Engineering and Technology*, *2*(5), 80-87.

Sudiajeng, L., Tarwaka, T., Sutapa, I. K., Sudana, M., & Yusuf, M. (2023). Ergonomic tetrapod reduces the MSDs risk and productivity of steel-bar assembly for reinforcement concrete beams. *International research journal of engineering, IT & scientific research*, *9*(1), 1-13.

Taib, M. F. M., Reza, N. A. A., & Sirat, R. M. (2021). Ergonomics awareness, working posture and muscle fatigue among industry workers and their relationship with musculoskeletal disorders (MSDs) Symptoms: a case study. *Jurnal Mekanikal*, 29-37.

Yusuf, M., Suarbawa, I. K. G. J., & Santiana, I. M. A. (2025). Analysis of potential ergonomic hazards in metal craft welding workers. *International Journal of Occupational Safety and Health*, *15*(2), 165-172.

Yusuf, M., Suarbawa, I. K. G. J., & Santiana, I. M. A. (2025). Factors Affecting the Workload of Horticultural Farmers in Agrotourism Areas. *Multidisciplinary Science Journal*, *7*(3), 2025136-2025136.

Yusuf, M., Suarbawa, I., Dewi, N. W. M. S., Sadiyani, N. W., & Sudana, I. (2025). Understanding Occupational Health and Safety Regulations and the Influence on Students' Behavior in Practical Workshops. *Kesmas*, *20*(2), 95-103.

Yusuf, M., Sudiajeng, L., Suryawan, K. A., & Sudana, I. M. (2022). Redesign of Ergonomic Worktables in

Reinforced Concrete Sheet Works Reduce Ergonomic Risk Level. In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science iCAST-ES, ScitePress Digital Library* (pp. 370-374).