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Development of an Ergonomic Based Adaptive Walker Design to Optimize Walking Mobility in the Elderly

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ABSTRACT

The increasing elderly population has led to a higher prevalence of mobility limitations associated with reduced muscle strength, musculoskeletal disorders, and postural instability. Conventional walkers often fail to accommodate anthropometric variations and shock absorption needs, resulting in non-neutral postures and elevated ergonomic risk. This study developed an ergonomics-based adaptive walker integrating an adjustable handle mechanism and spring-based shock absorption. A pre- and post-intervention experimental approach involving five elderly participants was conducted using the Rapid Upper Limb Assessment (RULA) method. Initial RULA scores ranged from 5 to 7, indicating high to very high-risk levels. After using the adaptive walker, the scores decreased to 2–5, representing a 44.83% reduction in the average risk level. Improvements were observed in neck, trunk, and wrist posture, indicating enhanced ergonomic alignment and walking stability

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1. INTRODUCTION

Population aging is an increasingly significant global phenomenon, with the proportion of older people continuing to increase along with advances in medical technology and improvements in living standards (Steverson, 2025; Bodiroza, 2025). According to the latest data from the World Health Organization (WHO) in its World Report on Aging and Health (2025) (Steverson, 2025), it is estimated that by 2050, the number of older people aged 60 years and over will reach 2 billion globally, or approximately 22% of the world's total population. The Central Statistics Agency (BPS) reported that in 2023, the number of older people will reach 29.7 million, or 10.8% of the total population, with a projected increase to 74.5 million by 2045 (Badan Pusat Statistik, 2023). This phenomenon poses significant challenges in the health sector, particularly related to the decline in physical function and mobility in older adults (Zhang et al., 2024).

Impaired walking mobility is often caused by conditions, such as osteoporosis, arthritis, muscle weakness, and postural imbalance (Liu & Bai, 2024; Zhang et al., 2024). Data from the Centers for Disease Control and Prevention (CDC) show that approximately 25% of older adults aged ≥ 65 years' experience difficulty walking or require mobility aids, which contributes to a fall risk of up to 30% per year (CDC, 2024). The 2018 Basic Health Survey (Risdekdas), updated in 2025 by the Indonesian Ministry of Health, indicates that 15.5% of older adults experience mobility limitations, with higher rates in rural areas due to limited access to rehabilitation services (Kemenkes, 2023; NCOA, 2025). Efforts to develop walking aids have been extensively researched, with various studies developing flexible walkers, foldable walkers, and brainstorming methods to improve walker function (Wang et al., 2025). However, existing walker designs do not adequately meet the needs of older adults, resulting in mobility difficulties (Aruona et al., 2025). Therefore, it is important to design adaptive walkers that follow ergonomic principles and conduct biomechanical evaluations (Gómez-Galán et al., 2020).

Various walker design developments have been conducted, but most still focus on structural modifications (Ma et al., 2022), folding systems (Rianmora & Poulpanich, 2022), or material efficiency without comprehensive ergonomic validation based on standardized posture assessment methods (Alves et al., 2025). The integration of user anthropometric adjustments with mechanical shock absorption systems evaluated quantitatively is limited in previous studies.

Conventional walkers generally have a fixed handle height and rigid leg structure, potentially causing non-neutral neck and trunk postures, wrist deviation, and decreased stability when used on uneven surfaces. These limitations indicate a research gap in the development of walking aids that simultaneously consider the anthropometric variations of older adults, biomechanical alignment of posture, and shock reduction through a measurable ergonomic evaluation approach.

This study developed an ergonomics-based

adaptive walker design to optimize walking mobility in the elderly. The novelty of this study lies in the integration of an adjustable handle mechanism based on the anthropometry of the elderly, a spring-based shock-absorbing system on all four walker legs, and quantitative ergonomic validation within a structured design framework. The Rapid Upper Limb Assessment (RULA) method was used in a pre and post-use experimental approach to objectively measure postural risk reduction, while the Pugh Concept Selection method was used to determine the best design alternative based on predetermined criteria (Guler & Petrisor, 2021). The proposed design integrates an adjustable handle mechanism based on anthropometric considerations and a spring-based shock-absorbing system on all four walker legs within a single integrated design framework. The effectiveness of the design was validated through an experimental approach before and after use of the device using the RULA method, resulting in quantitative and objective evidence of reduced ergonomic risks. This integrated and systematically validated approach is a key differentiator and significant contribution compared to previous walker development research

2. RESEARCH METHODS

Research on the development of an ergonomically based adaptive walker design was conducted experimentally in a laboratory to evaluate improvements in the independent walking mobility of the elderly. The evaluation was conducted by integrating the Rapid Upper Limb Assessment (RULA) and Pugh Concept Selection methods in the design and testing stages. The research concept is shown in Fig.1.

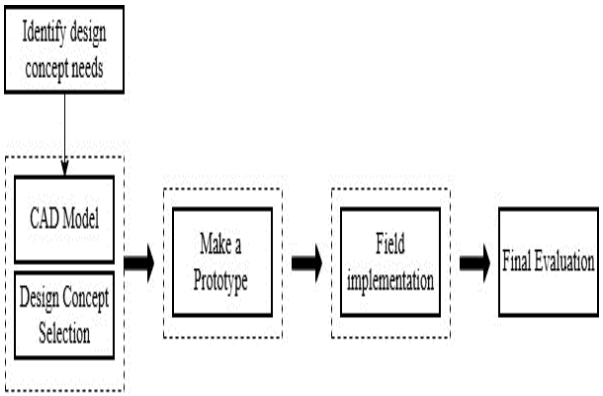


Fig.1. Schematic diagram of research

This schematic illustrates the systematic flow of adaptive walker development, starting from the identification stage of design concept needs to determine technical criteria based on user needs. The process continues with the integration of CAD model creation and design concept selection to finalize the digital design and choose the best solution using the Pugh Concept Selection method to compare several design alternatives based on the following criteria: ergonomics, comfort, stability, and independence of the elderly before entering the physical prototype creation stage (Honkala et al., 2007). After the prototype is completed, the tool is tested through field implementation using the RULA (Rapid Upper Limb Assessment) method to see its real performance when used by humans, which is then closed with a final evaluation to determine whether the development results have met the expected safety and functionality standards (Mouhib et al., 2025). The criteria used in the Pugh concept selection method were determined based on user needs identification and a literature review on elderly walking aids, including aspects of ergonomics, comfort, stability, safety, cost, and functional features. Each criterion was further translated into measurable sub-criteria to facilitate the evaluation of design alternatives.

The evaluation process was conducted by an expert panel consisting of three lecturers in industrial engineering with expertise in ergonomics and product design. Each expert independently assessed the design alternatives by comparing them with the baseline design using a qualitative scale (+1 for better, 0 for equivalent, and −1 for worse). The final decision was determined based on the cumulative score across all criteria, wherein the alternative with the highest positive score was selected as the preferred design**.** The experimental procedure in this study was carried out in the following stages:

a) Respondent Selection
Five elderly respondents with mild to moderate mobility limitations were selected as research participants. All respondents were conscious and able to walk with the assistance of a device. The participants were aged 60–72 years and in stable health during the testing period. The inclusion criteria for this study were as follows: (1) age ≥ 60 years, (2) experiencing mild to moderate mobility limitations, (3) being able to stand and walk with assistive devices, (4) not experiencing severe musculoskeletal injuries or acute conditions, and (5) being willing to participate in the entire research process. This study considered ethical aspects by ensuring that all respondents provided informed consent before testing was conducted.

b) Initial Condition Testing (Pre-Test)
Each participant was asked to walk using a conventional walker on the same trajectory under controlled environmental conditions. Walking activity was recorded using a camera.

c) Intervention Condition Testing (Post-Test)
The respondents then walked using the developed adaptive walker. The testing procedure was conducted on the same trajectory under the same conditions to maintain experimental consistency.

d) Standardization of Visual Data Collection
Recordings were conducted at three different angles (0°, 30°, and 35°) to obtain a comprehensive visualization of body posture. Each condition was repeated thrice to minimize unintentional movement variations.

e) Postural Angle Analysis
Video recordings were analyzed using Kinovea software to objectively measure the postural angles of the neck, trunk, arms, and wrists. The analysis was performed frame-by-frame to increase measurement accuracy and reduce subjectivity in visual assessments.

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f) RULA Score Assessment
The Rapid Upper Limb Assessment (RULA) score is calculated based on postural angle measurements. The assessment was conducted by two evaluators familiar with the RULA method to reduce the potential for subjective bias.

g) Data Validation and Reliability
The assessment results of both evaluators were compared to ensure score consistency. Repeated testing and angle analysis software were used to improve the validity and reliability of the measurement results.

h) Sample Size Justification
The limited number of respondents in this study aligns with the research objective, which is a preliminary study focused on the initial validation of the prototype design. Therefore, the sample size was deemed sufficient to identify potential ergonomic improvements before conducting further research with a larger number of respondents and more in-depth statistical analysis.

3. RESULTS AND DISCUSSION

3.1. Posture Assessment of the Elderly with a Conventional Walker

This study was conducted to assess the posture of elderly people while walking using conventional walkers, which pose a risk of musculoskeletal injuries, particularly to the legs, back, and neck (Jin et al., 2025). Posture assessment using video analysis captured using Kinovea software served as a basis for identifying areas with high ergonomic risks and as a reference for developing adaptive walkers. The assessment method used was the Rapid Upper Limb Assessment (RULA) to evaluate the level of ergonomic risk based on the angle of body posture during work activities. The body postures of five elderly participants while walking are shown in Fig. 2.



Fig. 2. Elderly walking posture angle value

The observed work postures showed non-neutral body angles, such as neck and torso tilt, as well as extreme positions of the arms and wrists. According research (Kee, 2022) assessment was conducted on three main components: Group A (upper arm, lower arm, wrist, and wrist twist), Group B (neck, torso, and legs), and the final RULA score based on the combination of the two. The recapitulation of Group A is explained in the Fig. 3.

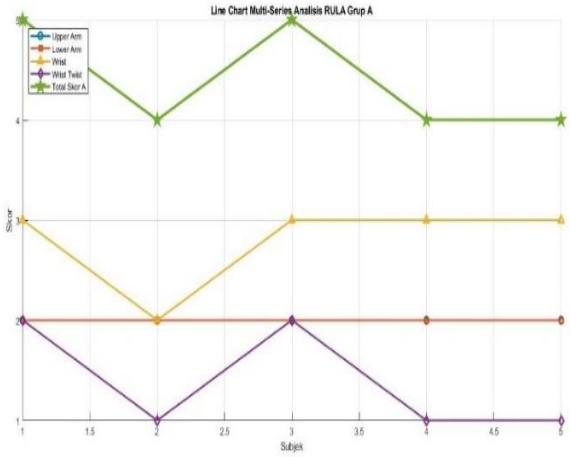


Fig. 3. RULA group (A) assessment

Fig. 3 shows that the total score of Group A on the graph has the highest value in Subjects 1 and 3, while Subjects 2, 4, and 5 have lower scores. This pattern indicates that the increase in the total score of Group A is directly correlated with the increase in wrist and wrist twist scores, and not with changes in upper arm or lower arm posture. Thus, it can be concluded that the wrist is the most dominant component in determining the level of ergonomic risk in Group A for the activities analyzed. A summary of the assessment of Group B is presented in Fig. 4.

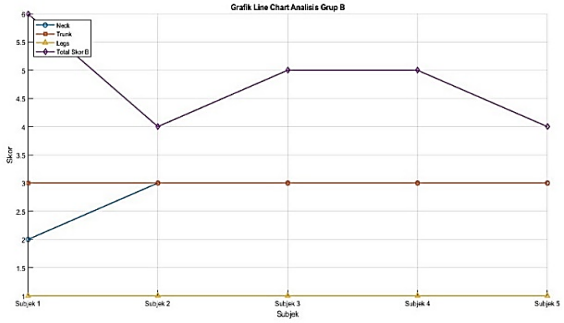


Fig. 4. RULA group (B) assessment

This assesses the neck posture, trunk posture, and leg stability. Participants 1, 3, and 4 received the highest scores of 6 and 5, indicating a hunched posture, sharply lowered neck, and unbalanced legs. These postures pose a significant risk of back and neck muscle strain if they are repeated or performed for prolonged periods.

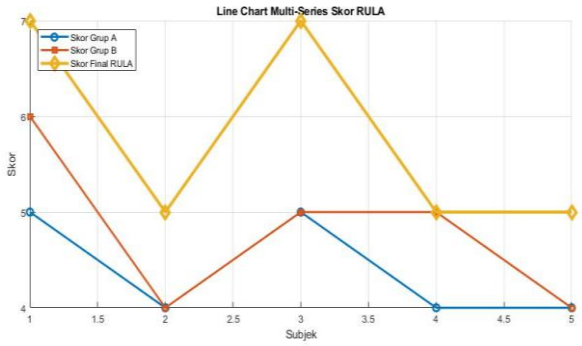


Fig. 5. Final RULA assessment

Fig. 5 shows the combined scores of Group A and Group B based on Table C of the RULA method. The most critical condition was seen in Subject 1 and Subject 3, who achieved a Final Score of 7. In the RULA methodology developed by Mcatamney & Corlett (1993), a score of 7 is the maximum value indicating that the subject's work posture is at an extreme risk level, so that profound changes to the work system or design must be made immediately (now) to prevent permanent musculoskeletal injury. Meanwhile, the other subjects (2, 4, and 5) had a final score of 5, which still indicates a significant biomechanical workload; therefore, investigation and changes to work methods are needed in the near future to reduce the risk level.

3.2. Adaptive Walker Design Specification Deveopment

After identifying user needs and formulating the design concept requirements in the previous stage, the next step is to translate these requirements into more operational technical specifications. These technical specifications aim to ensure a measurable and targeted design process and facilitate the selection of design alternatives. Table 1 presents the conversion from the design concept to technical design requirements, which will serve as a reference during the walker prototype design and concept selection stages.

Table 1 The elderly's need for adaptive walkers

No	Design Concept	Technical Requirments of Design
1	Handle mechanism that can be adjusted in height and angle	A manually operated rotating bolt-based folding hinge and locking system
2	Spring integration on walker legs	Spring mechanism with an outer diameter of 14 mm, a 2 mm wire, and a free length of 30–50 mm.
3	Using light but strong materials	Aluminum alloy material with a total weight of > 4 kg
4	Resistant to uneven surfaces	The use of springs can reduce shocks when walking on an uneven surface.
5	Anti-slip on the support legs	The sole was made of a hard and rough sponge with a square base.
6	Manual lock on the handle	M5 size rotating bolt
7	Soft and non-slip handle	Rubber material with a length of 12 cm
8	Unobtrusive aesthetics	Neutral and modern color design
9	Load capacity up to 100 kg	Aluminum alloy material is strong, anti-rust, and can withstand pressure.

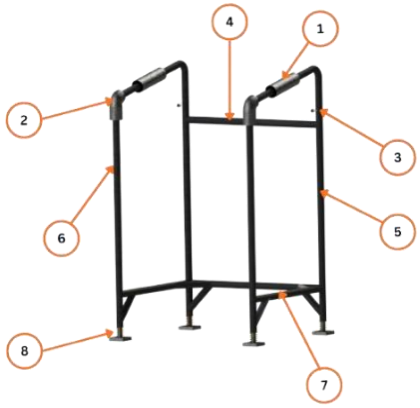
Table 2. Morphological chart

No	Functional Solution	Alternative (Design A)	Flow	Alternative (Design B)
1	Handle mechanism that can be adjusted in height and angle	The folding hinge + locking system based on rotating bolts works manually	● ↔ ● ↔ ●	Manual hinge + rotary bolt based lock works manually.
2	Spring integration on walker legs	The mechanism for using springs on walker legs	● ↙ ● ↗ ●	Patented walker legs made of solid aluminum with PU foam base (less flexible)
3	Using light materials but strong	Aluminium alloy, with total weight > 4 kg	● ↔ ● ↔ ●	Alluminium Solid, strong but weighs < 5 kg
4	Resistant to slippery and uneven surfaces	Use of springs and sponge soles	● ↙ ● ↗ ●	Full foam PU sole
5	Walker production costs	Aluminum alloy raw materials are cheaper and lighter	● ↙ ● ↗ ●	Aluminium solid raw materials are slightly more expensive and heavy but strong.
6	Manual lock on the handle	M5 size rotating bolt	● ↔ ● ↔ ●	M5 size rotating bolt
7	Soft and non-slip handle	Rubber material with a length of 12 cm, anti-slip.	● ↙ ● ↗ ●	Soft full foam material
8	Unobtrusive aesthetics	*Glossy finish, neutral black color*	● ↔ ● ↔ ●	*Glossy finish, grey, blue color*
9	Load capacity	Can withstand loads and pressure up to 100kg	● ↙ ● ↗ ●	Can withstand loads and pressure up to 120kg

Information: ● = Start from Design A; ● = Technical evaluation/comparison point; ↙ = Alternative A is better; ↗ = Alternative B is better; ↔ = Equivalent/similar function; and ● = End at Alternative

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Table 3. Alternative design A



No	Component	Technical Description
1	Grip/Handle	Made of aluminum alloy. The rubber-coated part is a place for the user to hold the walker for greater comfort and non-slip.
2	Main Hinge	Flexible connection system of rear support legs with grip
3	Locking bolt	The bolt acts as a manual lock when adjusting the grip height adjustment.
4	Middle connecting bar (Crossbar)	Horizontal bar connecting the left and right sides of the walker to increase the strength and stability of the frame.
5	Front frame/legs	The main support pole of the front walker which distributes the load to the lower part.
6	Rear frame/legs	The main support pole of the walker at the back which maintains the balance of the structure.
7	Lower brace	The reinforcing bars at the bottom serve to increase the strength of the structure and prevent the frame from bending.
8	Walker legs with springs	The foot part of the walker is equipped with a spring to maintain balance and make it easier for the elderly to lift the walker and is equipped with an anti-slip base.

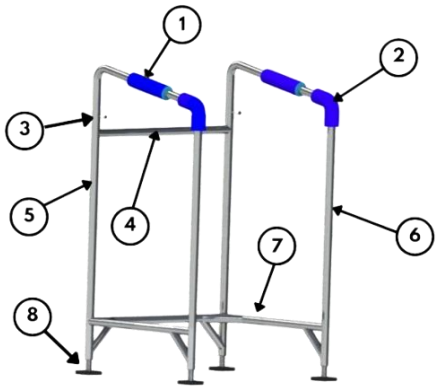
The technical specifications are derived from functional requirements and dynamic work environment conditions, while also considering comfort, safety, and ease of use. After compiling the technical specifications, various alternative technical solutions were explored using the Morphological Chart method (Hülagü & Timur, 2024). Table 2 represents the results of the morphological chart

Based on research Hussain et al. (2023) design A is an adaptive walker made primarily of aluminum alloy, designed to aid mobility in walking for the elderly. An aluminum alloy was chosen for its (Table 3). Design B is an adaptive walker alternative that prioritizes structural strength and comfort, primarily using solid aluminum (Table 4). This design also features manual locking and foam grips. Although heavier than Design A, it offers optimal comfort and stability.

3.3. Adaptive Walker Design Concept Assessment

The assessment of the adaptive walker design concept was conducted using the Pugh method, which is a concept selection method based on a comparison with the baseline. In this study, the evaluation was carried out by three lecturers as an expert panel, who

Table 4. Alternative design B



No	Component	Technical Description
1	Grip/Handle	Made of solid aluminum coated with PU foam as a place for the lansi to hold the walker for more comfort.
2	Main Hinge	Flexible connection system of rear support legs with grip
3	Locking bolt	The bolt acts as a manual lock for adjusting the height of the grip when used by the elderly.
4	Middle connecting bar (Crossbar)	Horizontal bar connecting the left and right sides of the walker to increase the strength and stability of the frame.
5	Front frame/legs	The main support pole of the front walker which distributes the load to the lower part.
6	Rear frame/legs	The main support pole of the walker at the back which maintains the balance of the structure.
7	Lower brace	The reinforcing bars at the bottom serve to increase the strength of the structure.
8	Walker legs	solid aluminum with PU foam sole

provided assessments based on ten predetermined sub-criteria. These criteria include aspects of performance, durability, cost, safety, and features, such as folding efficiency, ease of installation, material strength, seating comfort, and compatibility with work clothing. Before evaluating the developed design alternatives, a baseline design is first established as a comparative reference in the Pugh concept selection method. The baseline design is a commonly used conventional walkthrough with a basic structure that serves as a standard of comparison for evaluating the strengths and weaknesses of the proposed design alternatives. Table 5 presents a visualization of the baseline design and its main components.

This baseline design has limitations regarding height adjustment, lacks a shock-absorbing system, and does not consider anthropometric variations in elderly users. These limitations formed the basis for the development of alternative designs A and B, which were assessed using the Pugh Concept Selection method.

Table 6 shows that Design A received the highest total score of 6 positive points, and hasn't negative points. (Azwir et al., 2020) said This reflects that Design A is able to meet most of the technical needs and preferences of the elderly. The striking advantages are its light weight, adjustable handle mechanism, and the integration of springs in the walker's legs. Design B received three positive points and four negative points owing to its height adjustment mechanism and manual restrictions. However, this design does not meet the main criteria, as the method used by (Indrawan et al., 2025) the comparison of the mismatch of the weight of the walking aid, the use of raw materials, and production costs, which reduces the ergonomic value of the walking aid. Based on the results of this evaluation, Design A was determined to be the best alternative and recommended for further development, namely, prototyping and testing. Design B was discontinued because it did not meet enough of the main criteria.

The results of the RULA score reduction indicate that the adaptive walker design has the potential to improve posture in older adults during walking. However, it should be noted that the measurements in this study were limited to postural parameters and did

Table 5. Base design



No	Component	Technical Description
1	Handle	Aluminum alloy grip without sponge or rubber layer.
2	Connecting cross	Horizontal connecting rods for structural stability.
3	Main frame	Fixed height aluminum alloy main frame.
4	Support legs	Four support legs without damping system (without springs).
5	Lower brace	The reinforcing bars at the bottom serve to increase the strength of the structure and prevent the frame from bending.

Table 6. Adaptive walker design concept assessment

Criteria	Sub Criteria	Alternative Design Concept		
		Base	A	B
Performance	Grip height adjustment mechanism	0	+1	+1
	Spring integration on walker legs	0	+1	-1
	Maximum total weight > 4 kg	0	+1	-1
Durability	Using light but strong aluminum alloy material	0	+1	-1
	Resistant to slippery and uneven environmental surfaces	0	0	0
Cost	Low production costs	0	0	-1
Safety	Manual locking system on the grip	0	+1	+1
Features	Non-slip pads with rubber material on the grip	0	+1	0
	Socially acceptable aesthetics (modern design)	0	0	0
	Load capacity up to 100 kg	0	0	+1
Total (+)			6	3
Total (0)			4	3
Total (-)			0	4
Final Score			6	-1
Ranking			1	2

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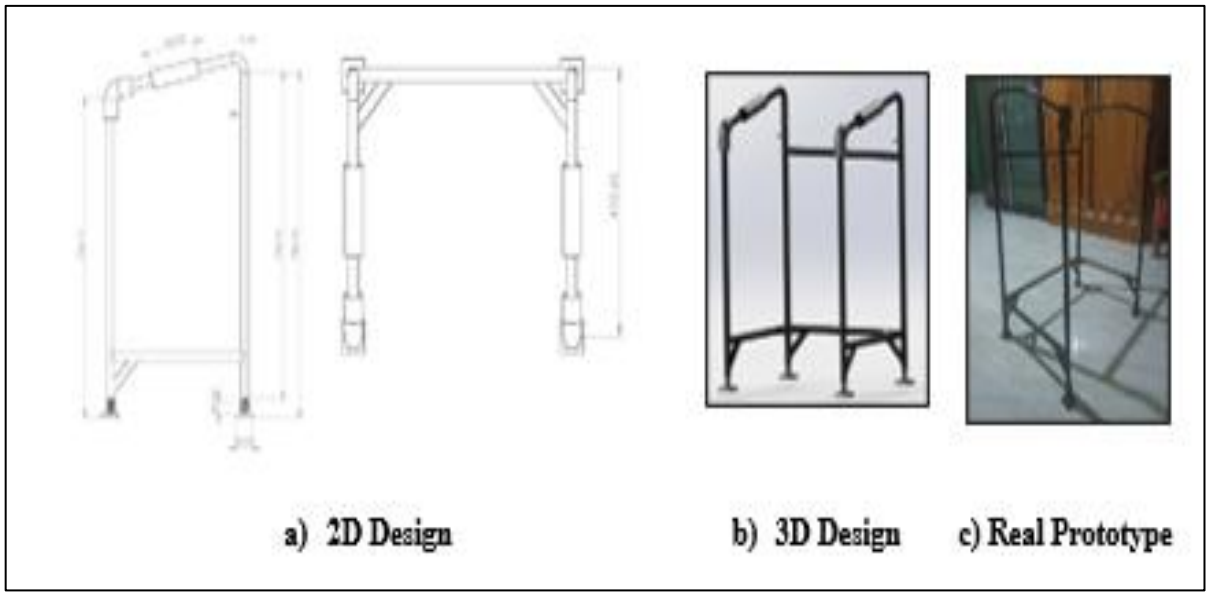


Fig. 6. Making Design prototype

not include direct biomechanical measurements, such as ground reaction forces or vibration damping characteristics. Therefore, the effectiveness of specific design features, particularly the spring mechanism, cannot be conclusively established. Further studies incorporating comprehensive biomechanical analyses and larger sample sizes are required to validate the effectiveness of the proposed design more robustly

3.4. Making Adaptive Walker Prototype

After the concept selection stage was conducted using the Pugh method, a prototype was created based on Design A, which was selected as the best alternative. This prototype creation aimed to evaluate the extent to which the developed design could be implemented in practice from a functional, ergonomic, and visual perspective. According research (Lourenço & Pitarma, 2022) the three-dimensional modeling process was carried out using SolidWorks 2021 software to obtain accurate visualizations and produce complete engineering drawings. Fig. 6 shows an isometric view of the model of the adaptive walker design.

3.5. Adaptive Walker Prototype Testing

A physical prototype of the tool has been realized according to the optimal design produced, and now validated through working tests of the tool to ensure the suitability between the optimal design and the actual realization (Wijaya et al., 2024), particularly related to musculoskeletal and muscle weakness and body balance in the elderly when walking. The test was conducted using the RULA method that had been used in the previous assessment, with the same approach and procedure so that the results could be compared directly. The analysis was carried out based on measurements of body posture angles through image captures obtained from videos when the elderly was walking. The assessment was conducted on the same five subjects as during the initial data collection, who had been observed using a conventional walker with details of taking three variations of front angles, namely angles (0°, 30°, and 35°) on the adaptive walker.



Fig. 7. RULA testing. (A) Walker adaptive angle 0°, (B) Walker adaptive angle 30°, (C) Walker adaptive angle 35°

The results reveal a significant change in the subject's body posture after using the adaptive walker prototype (Fig. 7). The visualization of Subject 5's posture when walking using three walker handle angles: (5A) 0°, (5B) 30°, and (5C) 35°. This finding is in line with (Stanton et al., 2005). The upper arm angle was below 15°, the upper arm angle was between 60°and 100 °, and the wrist had a neutral bending angle of 0°to 15 °. The neck angle, which previously showed a sharp value, is now neutral (7.6°, 6.3°, and 0.0°), as well as the back angle, which is in an upright position (12.8°, 3.8°, and 0.7°), and the leg position is well supported at an angle range of 166°. This condition differs from that when using a conventional walker, in which Subject 5 experienced a hunched back angle and a forward-leaning neck. The following table and graph present the data from the Group A test results obtained when using the adaptive walker prototype.

Group A is shown in Fig. 8. It can be observed that Group A scores decreased evenly across almost all subjects. While many subjects previously had scores of 4–5, after using the prototype, the highest score only

reached 4, such as in Subjects 1A-1B, 3A-3B, and 4C. The other subjects were in the 2 range, indicating that the posture of the upper arm, forearm, and wrist was much better. This decrease indicates that adaptive walkers are successful in reducing the risk of elderly people experiencing musculoskeletal injuries.

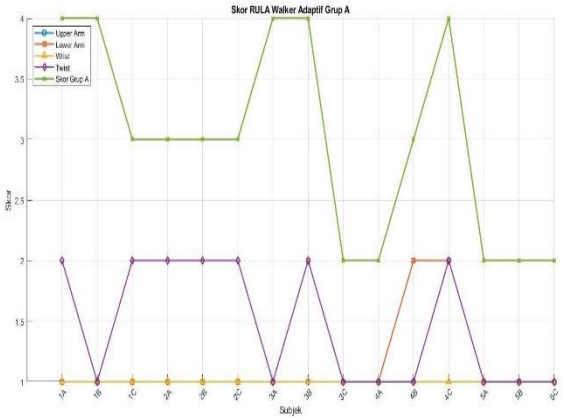


Fig. 8. RULA group (A) work posture assessment

Fig. 9 shows the results of the Group B assessment, which included neck posture, trunk posture, and leg stability. If previously extreme scores of 6 and 5 were found in some subjects 1, 3 and 4, after using the prototype, the highest score only reached 4, and the majority of subjects obtained a score of 2. These results demonstrate significant improvements in body stability and foot position.

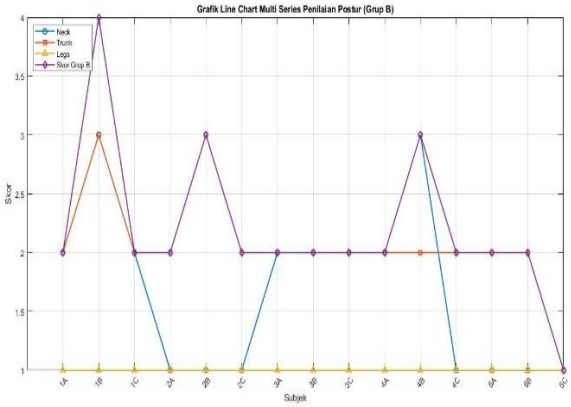


Fig. 9. RULA group B work posture assessment

Fig. 10 shows the final RULA score results after using the adaptive walker. It can be seen that the highest final score only reached 5, with most subjects obtaining scores of 3 and 2. In comparison with the initial conditions before the intervention, where some subjects obtained a score of 7 (very high category), this decrease shows the real success of the prototype in improving work posture. A significant example is Subjects 1 and 3, who previously obtained a final RULA score of 7; now, after using the adaptive walker, it has dropped to 5 in 1B, and even the lowest in 3C has a score of 2.

Fig. 11 presents a comparison of RULA scores obtained using a conventional walker and the proposed adaptive walker. A significant improvement in ergonomic conditions was observed following the intervention. Prior to the intervention, all five participants exhibited relatively high RULA scores ranging from 5 to 7, indicating high to very high ergonomic risk. After using the adaptive walker, all participants showed a noticeable reduction in RULA scores. Overall, these findings suggest that the proposed ergonomic intervention has the potential to improve working posture and reduce the risk of musculoskeletal disorders among elderly users. To strengthen the analysis, the average change in RULA scores between the pre- and post-intervention conditions was calculated, showing a reduction of 44.83%, which indicates a descriptively significant improvement in posture. However, inferential statistical tests (e.g., paired t-tests) were not conducted because of the limited sample size. Therefore, the results should be interpreted as preliminary and require further validation through studies involving a larger number of participants.

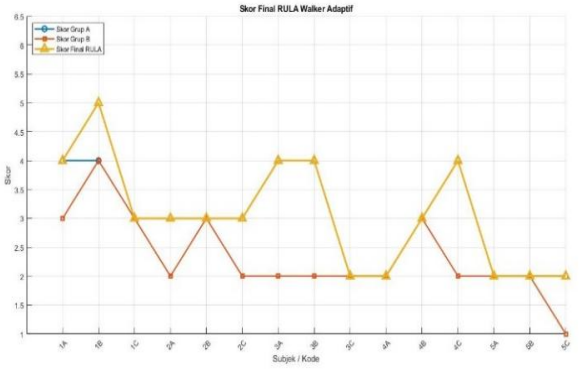


Fig. 10. RULA work posture assessment final score

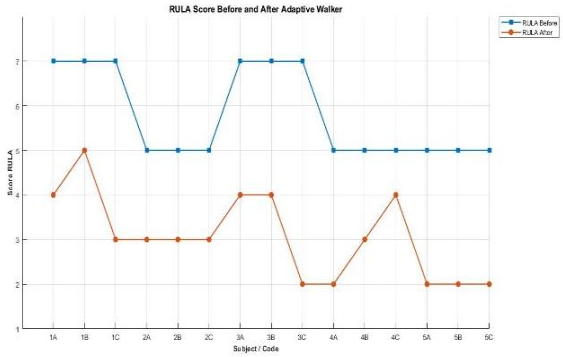


Fig. 11. RULA work posture assessment before and after

The findings of this study are consistent with previous research on walker design and ergonomic interventions for older users, which highlights that an adjustable handle height and proper ergonomic alignment can significantly improve walking posture and reduce musculoskeletal strain. In line with these studies, the proposed adaptive walker demonstrated improvements in neck, trunk, and upper limb posture, as reflected by a reduction in RULA scores.

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Furthermore, prior research on assistive walking devices emphasizes the importance of stability and comfort in reducing fall risk and enhancing user confidence. The integration of a spring mechanism in this study is conceptually aligned with these objectives; however, its biomechanical effectiveness, such as vibration damping or impact reduction, was not directly measured. Compared with previous studies that employed larger sample sizes and comprehensive biomechanical analyses, this study remains limited as a preliminary or pilot-scale evaluation. Therefore, although the results are promising, they should be interpreted as initial findings that require further validation through more rigorous experimental designs.

4. CONCLUSION

This study successfully developed an ergonomics-based adaptive walker design with modular features in the form of an adjustable handle mechanism using a folding hinge system and an M5 rotary bolt manual lock, as well as spring integration on all four walker legs. Through the Pugh Concept Selection method, Design A was selected as the best alternative with a score of six positive points out of ten assessment criteria and identified as the most suitable design to accommodate variations in the physical needs of the elderly. The test results obtained using the RULA method showed substantial improvements in posture, with the RULA score decreasing from the very high-risk category (score 7) when using a conventional walker to the range of 2–5 after using the adaptive walker, with observed improvements in postural parameters, including more neutral neck angles (0.0°–7.6°), a more upright trunk position (0.7°–12.8°), improved arm posture (scores of 1–2), and more stable leg support (approximately 166°).

The integration of the spring mechanism is suggested to contribute to improved walking comfort and stability, particularly on uneven surfaces; however, its effectiveness in reducing impact forces was not directly measured in this study. Similarly, the adjustable handle allows elderly people to maintain a more ergonomic posture and may help reduce muscle tension and the risk of musculoskeletal disorders. Overall, this adaptive walker demonstrates potential to improve walking posture and support mobility independence in elderly users. However, further studies involving larger sample sizes and comprehensive biomechanical measurements are required to rigorously validate the effectiveness of the proposed design.

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REFERENCES

Alves, J., Lima, T. M., & Gaspar, P. D. (2025). Novel approach for ergonomic assessment of musculoskeletal risks for OHS in high-demand and complex manual tasks − case study of polishing industry. *Safety Science*, *191*. https://doi.org/10.1016/j.ssci.2025.106969

Aruona, V. A., Harris, N., Munera, M., & Cifuentes, C. A. (2025, May). Reimagining assistive walkers: An exploration of challenges and preferences in older adults. In *2025 International Conference On Rehabilitation Robotics (ICORR)* (pp. 1659-1664). IEEE. https://doi.org/10.1109/ICORR66766.2025.11063188

Azwir, H. H., Wardani, E. F., & Oemar, H. (2020). Perbaikan Desain Produk Reamer Menggunakan Metode Taguchi Untuk Memaksimalkan Durability. *JISI: Jurnal Integrasi Sistem Industri*, *7*(2), 101–110. https://doi.org/10.24853/jisi.7.2.101-110

Badan Pusat Statistik (2023). *Statistik Penduduk Lanjut Usia 2023.* Badan Pusat Statistik. https://www.bps.go.id/id/publication/2023/12/29/5d308763ac29278dd5860fad/statistik-penduduk-lanjut-usia-2023.html

Bodiroza, A. (2025). *Ageing*. United Nations Population Fund Pcific & Asia(UNFPA). https://asro.unfpa.org/en/topics/ageing?utm_

CDC. (2024). *Older Adult Falls Data*. CDC (Centers for Disease Control and Prevention). https://www.cdc.gov/falls/data-research/

Fakhouri, F. S., Fakhouri, A. S., Ijaz, M. F., Alotaibi, M., & Almalki, A. (2023). Design of an After-Fall-Assistive Device for Elderly Patients by Finite Element Methods. *Journal of Disability Research*, *2*(4), 6–12. https://doi.org/10.57197/JDR-2023-0043

Gómez-Galán, M., Callejón-Ferre, Á. J., Pérez-Alonso, J., Díaz-Pérez, M., & Carrillo-Castrillo, J. A. (2020). Musculoskeletal risks: RULA bibliometric review. *International journal of environmental research and public health*, *17*(12), 4354. https://doi.org/10.3390/ijerph17124354

Guler, K., & Petrisor, D. M. (2021). A Pugh Matrix based product development model for increased small design team efficiency. *Cogent Engineering*, *8*(1). https://doi.org/10.1080/23311916.2021.1923383

Honkala, S., Hämäläinen, M., & Salonen, M. (2007). Comparison of four existing concept selection methods. In *DS 42: Proceedings of ICED 2007, the 16th International Conference on Engineering Design, Paris, France, 28.-31.07. 2007* (pp. 125-126). https://pss.designsociety.org/download-publication/25384/Comparison+of+Four+Existing+Concept+Selection+Methods

Hülagü, R., & Timur, Ş. (2024). *Archives of Design Research*, *37(1), 27-*, 27–40. https://doi.org/10.15187/adr.2024.02.37.1.27

Hussain, M. R., Haron, N. A., Effendi, R. A. A. R. A., Ibrahim, R., Sulaiman, R., Ahmad, S. A., Rokhani, F. Z., Ashari, A., Hassan, M. K., Dolah, M. S., & Ramli, S. H. (2023). Walking Frame Design Recommendation Based on Experience of Elderly User, Carer, and the Industry in Kuala Lumpur & Selangor, Malaysia. *Malaysian Journal of Public Health Medicine*, *23*(1), 261–271. https://doi.org/10.37268/mjphm/vol.23/no.1/art.1899

Indrawan, R., Bisono, F., Setiawan, A, T., Purnomo, A, D., Rosalina, A., & Fajardini, A, R. (2025).

Pemilihan Konsep Desain Hand Lift Manual Kapasitas 1 Ton Dengan Metode Ulrich. *Seminar Nasional Terapan Riset Inovatif (SENTRINOV)*, *11*(1), 399–405.

Jin, X., Dong, Y., Yang, L., Huang, W., Cao, L., Zhang, Z., & He, L. (2025). Ergonomic interventions to improve musculoskeletal disorders among vehicle assembly workers : a one - year longitudinal study. *BMC Public Health*, 1–12. https://doi.org/10.1186/s12889-025-21798-1

Kee, D. (2022). Systematic comparison of OWAS, RULA, and REBA based on a literature review. *International journal of environmental research and public health*, *19*(1), 595. https://doi.org/10.3390/ijerph19010595

Kemenkes. (2023). *Survei Kesehatan Indonesia (SKI) 2023*. Badan Kebijakan Pembangunan Kesehatan. https://www.badankebijakan.kemkes.go.id/

Liu, W., & Bai, J. (2024). The correlation of gait and muscle activation characteristics with locomotion dysfunction grade in elderly individuals. *Front. Bioeng. Biotechnol*, *12*(August), 1–15. https://doi.org/10.3389/fbioe.2024.1372757

Lourenço, M. L., Pitarma, R. A., & Coelho, D. A. (2022). A design contribution to ergonomic pc mice development. *International journal of environmental research and public health*, *19*(13), 8126. https://doi.org/10.3390/ijerph19138126

Ma, C., Guerra-Santin, O., & Mohammadi, M. (2022). Smart home modification design strategies for ageing in place: a systematic review. *Journal of Housing and the Built Environment*, *37*(2), 625–651. https://doi.org/10.1007/s10901-021-09888-z

Mcatamney, L., & Corlett, E. N. (1993). *RULA : a survey method for the investigation of world-related upper limb disorders*. *24*(2), 91–99. https://doi.org/10.1016/0003-6870(93)90080-s

Mouhib, H., Amar, S., Elrhanimi, S., & El Abbadi, L. (2025). A Comprehensive Review of Human Factors and Ergonomics in Industry 5.0. *Engineering Proceedings*, *112*(1), 61. https://doi.org/10.3390/engproc2025112061

NCOA. (2025). *Get the Facts on Falls Prevention*. National Council on Aging (NCOA). https://www.ncoa.org/article/get-the-facts-on-falls-prevention/

Rianmora, S., & Poulpanich, K. (2022). Concept Development in a Walking Assistive Device: Offset Handle With a Small Base Area. *International Journal of Knowledge and Systems Science*, *13*(1). https://doi.org/10.4018/IJKSS.306259

Stanton, N; Hedge, A; Brookhuis, K; Salas, E; Hendrik, H. (2005). *Handbook of Human Factors and Ergonomics Methods*. CRC PRESS. https://eprints.ulbi.ac.id/1709/

Steverson, M. (2025). *Ageing and health*. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

Wang, T., Zhao, Y., Zhang, X., Xie, Y., & Pang, L. L. L. (2025). Design of walking aids for the elderly based on the Kano-AHP-FEC method. *Scientific Reports*, *15*(1), 1–15. https://doi.org/10.1038/s41598-025-85540-y

Wijaya, D. K., Suprijono, H., Santoso, H. A., Kusmiyati, K., & Muchti, M. A. R. (2024). Design for Manufacturing and Assembly Optimization of Home-Scale Biodigester-Composter Using VDI 2222 and Finite Element Analysis Methods. *Jurnal Teknik Industri: Jurnal Keilmuan Dan Aplikasi Teknik Industri*, *26*(2), 157–170. https://doi.org/10.9744/jti.26.2.157-170

Zhang, B., Wang, Z., & Li, Z. (2024). Mobility Aid Design for the Elderly (MADE): a design thinking approach using a smart walker as a case study. *Humanities and Social Sciences Communications*, *11*(1). https://doi.org/10.1057/s41599-024-04007-z

http://dx.doi.org/10.30656/intech.v12i1.11895